Final Design Report

Intermediate Energy X-Ray Collaborative Development Team

Sector 29

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1 Introduction

We are designing a new variable polarization, small spot size, high-resolution beamline for the Advanced Photon Source (APS), covering the energy range 250 to 2500 eV which is to serve two experimental endstations. One will be dedicated to "high"-energy (~1000 eV) angle-resolved photoemission spectroscopy (ARPES), which is a *bulk* probe of the low-energy excited states in condensed matter while the other will be dedicated to resonant soft x-ray scattering (RSXS), which is a direct probe of electronic ordering. ARPES and RSXS are complementary techniques both technically and scientifically and are of interest to an overlapping scientific community.

The source, an electromagnetic variable polarizing undulator (EMVPU), will be optimized for maximum brilliance and flux in the range of (10^{14}-10^{15} photons/sec/0.1%bw) and provide radiation with variable linear polarization and circular polarization. Electromagnets will produce a quasiperiodic field to suppress higher order harmonics. A focusing variable line spacing plane grating monochromator (In-focus VLS-PGM) will provide a resolving power of 2,500 to 50,000 across the 250 to 2500 eV energy range with three gratings: a high-flux high energy grating, high-flux low energy grating and a high resolution grating. Additional focusing of the beam via Kirkpatrick-Baez (KB) pairs produce a spot size on the order of $\sigma = 2$ μm for the ARPES branch and a low beam divergence on the order of $\sigma = 40$ μrad for the RSXS branch.

The application of photoelectron and x-ray spectroscopy in the 250 to 2500 eV energy range has the potential to significant advance our knowledge of condensed matter science by elucidating the low energy electronic excitations in bulk materials and artificial structures. These low energy excitions are what govern most of the physical properties in materials. Details of the photoelectron and x-ray spectroscopy experiments to be conducted are outlined in the next section.

The proposed experiments, by their very nature, involve highly complex, ultrahigh vacuum set-ups with high-resolution electron energy or photon analyzers and in-vacuum goniometers, requiring painstaking alignment, bakeouts, *etc*. To run such experiments on a multi-purpose beamline would require using a large amount of beamtime for experimental setup, inevitably compromising productivity. Only a dedicated facility with associated beamline scientist(s), in the model implemented at the ESRF and SPring-8, has any real chance of success. To this end, a collaborative development team (CDT) has been formed with the APS, who is committed to contribute to construction, maintenance, operation, future improvements, and to provide the infrastructure for General User proposal review and access.

2 Scope of Scientific Program

2.1 Vision and Goals

One of the grand challenges for condensed matter physics in the 21st century is to understand the physics of materials that exhibit competing interactions. We refer specifically to materials in which several energy scales, such as valence bonding, Coulomb repulsion, and the kinetic energy of mobile electrons, are similar in size. The resulting ground state is a subtle compromise between these effects. These materials exhibit a startling array of electronic phases and a heightened sensitivity to external perturbations including changes in temperature, applied electric or magnetic fields, pressure, or nanopatterning. Two common examples are the manganese-oxides, in which small changes in applied magnetic field or temperature lead to large changes in magnetization or resistance, and the copper-oxides, which with increasing carrier density evolve from an antiferromagnet to a spin glass to a *d*-wave superconductor to a regular metal. These effects are driven, it is believed, by a competition between valence bond order and the kinetic energy of valence electrons. Other examples of such systems include spin ladder compounds, which have a spin gap and show charge ordering but become superconducting under pressure, and the triangular cobaltates which show frustrated ferrimagnetism and charge order but superconduct with the intercalation of water. In most of these cases low-dimensionality plays a crucial role by amplifying the quantum fluctuations. By patterning these materials into nanoscale structure it may be possible to produce materials with new and even more novel behavior.

Two conspicuous traits of materials with competing interactions, whether patterned or in single crystal form, are (1) a complex electronic excitation spectrum, resulting from the emergence of low energy collective modes, and (2) the emergence of new electronic length scales. To investigate these two categories of phenomena, we are developing an intermediate energy (IEX) beam line at the Advanced Photon Source (APS) with both a dedicated APRES endstation and a dedicated RSXS endstation. These endstations will be on separate branch lines but will share the same source and beamline optics.

2.2 Electron Spectroscopy – ARPES

By measuring the kinetic energies of electrons following irradiation with monochromatic x-rays ARPES is used to determine electronic structure information. Such experiments aim to elucidate the low energy electronic excitations in materials, which govern most of their physical properties. To date, the energy resolution requirements of ARPES (10-30 meV) have required the use of relatively low energy x-rays (<100 eV). But unfortunately, the inelastic mean free path of the electrons is only ~0.5 nm at these energies, so the surface makes a major contribution to the spectra. By increasing the incoming photon energy, the mean-free path of electrons increases exponentially. For example, for 1000 eV photons, the mean free path of electrons reaches 2-3 nm, making it possible to study the bulk properties of materials. To be more quantitative, in a simple exponential attenuation model the surface fraction (SF) is $1 - exp(-d/l)$, where d is the "surface" length and l is the mean free path. For conventional ARPES (~50 eV), $d = 0.5$ nm and $l = 0.5$ nm resulting in an SF = 0.63. However, by going to 1000 eV, l increases to 2.5 nm, resulting in a SF = 0.18. Therefore, the bulk to surface contrast is increased by 350%. Additionally, by varying the photon energy, say between 250 eV and 2000 eV, a comparison of the electronic structure of the bulk to that of the surface is possible.

2.3 X-ray Spectroscopy – RSXS

RSXS is a new diffraction technique in which sensitivity to charge and spin ordering is achieved by tuning the x-ray energy to atomic transitions, which weight the valence band. Intermediate-energy x-rays (250 – 2500 eV) are particularly powerful in this regard as they access the K edges of nitrogen through sulfur, the L edges of the transition metals, and the M edges of the rare earths, which probe the valence bands of most known strongly correlated electron systems. RSXS is therefore the natural probe of any kind of translational symmetry breaking in these systems and has recently been used to study charge transfer at an oxide interface, orbital ordering in manganatites, Wigner crystallization in spin ladders, and spectral weight modulations in stripe phases. Unfortunately, facilities in the United States for RSXS are currently very primitive. The proposed facility will provide full angular flexibility, access to liquid helium temperatures (~ 10 K), polarization tunability, fluorescence rejection optics for reducing the background known to plague this technique, reduced stray light, and a factor of 50 higher intensity than the most powerful source currently available.

2.4 Collaborative Development Team

The Intermediate-Energy X-ray Collaborative Development Team (IEX-CDT), a close collaboration between the APS and Principle Investigators from the University of Illinois-Urbana Champaign and the University of Illinois-Chicago has been formed to develop, build and operate the IEX beamline, which is dedicated to the study of collective electronic phenomena in strongly interacting electron systems with intermediate energy x-rays. This collaboration was established after the Principal Investigators underwent extensive and stringent reviews by external referees and committees appointed to advise the APS. The fact that only four sectors remain at the APS necessitated a careful selection. As part of the selection process, each project was required to hold workshops in order to gauge the interest of community and the IEX-CDT was assigned Sector 29 as the site for the IEX beamline. Inherent in the agreement with the APS is the availability of the facility to General Users, which, through their programs, greatly extends the usefulness of this facility, not only to the science of materials, but the training of students in general.

As part of the agreement with the APS the facilities outline here will be maintained and operated by the APS. More importantly, the APS will contribute between \$3 million to \$4.9 million towards the construction, including the design and construction of the undulator, outfitting lab and office space, the beam line safety system, etc. The project will also benefit from the engineering expertise, strict safety oversight, and quality assurance procedures in place at the APS. The Principle Investigators were awarded an NSF grant for \$3.9M over a period of three years, which will be used to cover the cost of the beamline and the end station. A detailed cost and schedule breakdown is shown in Appendix A.

3 Insertion Device: EM-VPU

3.1 Scientific Case for Undulator Parameters

The scientific mission of the IEX-CDT, to investigate collective excitations in strongly correlated electron systems via ARPES and RSXS, and requires the use of photons in the 250 to 2500 eV energy range. The advantage in using higher energy x-rays in ARPES is the increased bulk sensitivity, due to the increased elastic escape depth of the higher kinetic energy photoelectrons. This increase in bulk sensitivity is particularly important in studying correlated electron materials. The novel properties of these materials result from a delicate interplay of interactions (Coulomb, lattice, spin, *etc*.) with similar energy scales. Small differences in the energetics like the difference between the surface and the bulk can lead to dramatically different properties. In addition to being able to access the valance band of these systems, this range of photon energies will access to the K edge of oxygen, the $L_{2,3}$ edges of the transmission metals, and the $M_{4,5}$ edges of the rare earths, enabling the study of species dependent charge and spin ordering with RSXS. Having this range is extremely valuable as it also access Bragg peaks. This aids in orienting the sample in situ, which for the *(101)* direction, a typical perovskite requires an energy of > 2000 eV.

The ability to use circularly polarized photons and switch their helicity will provide added insight. For example, in ARPES experiments, one can determine the symmetry of the initial states by using polarization selection rules. Also, novel experiments use circular polarization to examine unusual phenomena such as time reversal symmetry breaking. In addition, circular polarization is also critical in the study of ferro- and ferrimagnetic materials in both ARPES and RSXS.

The high intensity provided by IEX beamline should also enable new science. For example, a factor of 50 increase in flux over the current state of the art RSXS experiments, should permit, for example, detection of surface states which are probably responsible for the checkerboard ordering observed in $Ca_{2-x}Na_xCuO_2Cl_2$ but are localized to 1 nm instead of 50 nm, or the very small degree of charge ordering believed to occur in $La_{2-x}Sr_xCuO_4$ or La_2CuO_{4+y}.

3.2 Technical Specifications of Undulator

The IEX beamline will be located in Sector 29 of the APS and make use of a standard 5 m straight section for the 4.8 m long insertion device which is being developed by the APS Magnetic Devices group. One of the requirements for the device is the ability to operate the device in varying amount of quasi periodicity. The technique of using quasi-periodicity allows one to shift the higher harmonics to non-integer values; as a result, the optics reject the higher harmonics. The net gain in signal to noise on the detectors is huge compared to the loss of intensity due to quasi-periodic device. The CDT team worked closely with the APS magnetic devices group over a course of a year to optimize performance while maximizing the intensity across the required energy range. The operating modes of the APS imposed some minimum requirements. Both an APPLE II style permanent magnet device and an electromagnet device were evaluated; the electromagmentic device was ultimately chosen due to its flexibility in the various operating modes. APS has built two 4 period prototypes: a 12 cm period device and a

12.5 cm period device. The final device will have period length of 12.5 cm and a total of 38 periods and is expected to operate in the range of 250 to 2500 eV in the first order. Details of the calculations for source selection are described in Appendix G. Also shown are details of the design of the device.

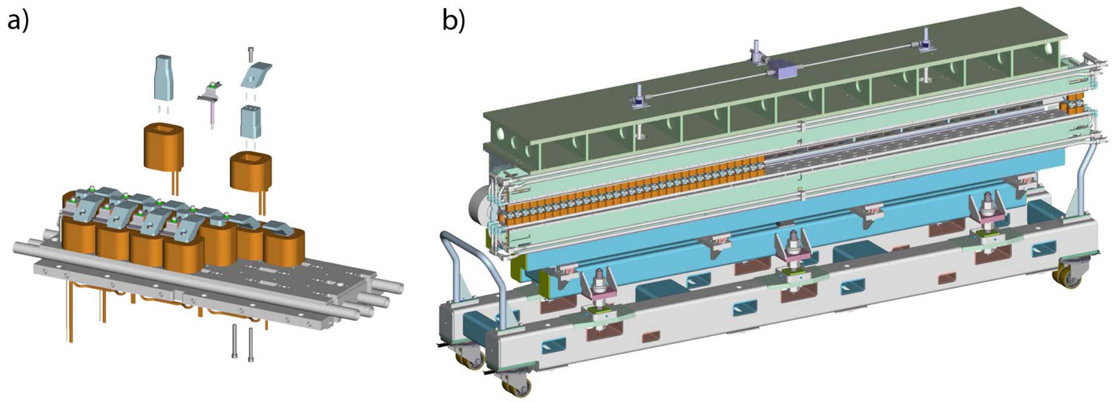


Figure 1. Schematic of the IEX undulator design consisting of a steel core with vanadium permendur poles where the B_x poles are on the outside and the B_y poles run down the middles.

Figure 1 above is the Schematic of the electromagnetic variable polarizing Undulator designed for IEX beamline. The parameters of the electron source and those of the insertion device (ID) are listed in Table 1. The device can be tuned down to 250 eV in horizontal polarization and down to 440 eV in vertical and circular polarization. The 440 eV limit is due to vertical apertures in the storage ring.

General	Period	12.5 cm
	Gap	10.5 mm
	Number of Periods	38
Horizontal Linear Polarization	Minimum Photon Energy	250 eV
	Require vertical effective field	4510 Gauss
	Current density in copper conductor	4.7 Amp/mm^2
	Current	47.6 Amp
	Turns per coil	62
	Amp-turns	2951
	Watts per coil	44.9 Watts
	Total number of coils	152
	Total power	6630 Watts
	Maximum coil temperature	100 °C
Vertical Linear Polarization	Minimum Photon Energy	440 eV
	Require horizontal effective field	3310 Gauss
	Current density in copper conductor	4.9 Amp/mm^2
	Current	50.3 Amp
	Turns per coil	46
	Amp-turns	2314
	Watts per coil	44.2 Watts
	Total number of coils	304
	Total power	11868 Watts
	Maximum coil temperature	100 °C
Circular Polarization	Minimum Photon Energy	440 eV
	Required horizontal and vertical effective field	2340 Gauss
	Current at vertical effective field	20.7 Amp
	Current at horizontal effective field	34.2 Amp

Table 1. Operating parameters for the IEX EM-VPU.

Users will be able to define the operational modes of the device including the energy, polarization at the sample and the degree of quasiperiodicity. Ramping down the current on specific poles allows for the continuous tuning from fully periodic to quasiperiodic. This control enables users to select the optimal x-ray beam parameters for their experiment balancing overall flux (periodic) with suppression of higher order light (quasiperiodic). In the quasiperiodic mode of operation there is an 18% reduction in the first harmonic but a 90% reduction in the third and higher odd orders, thus dramatically improving the signal to noise ratio (See Figure 2). With the use of trim coils and tweaks to the pole geometry, the undulator will produce purely horizontal (vertical) linearly polarized light or left (right) circularly polarized light at the sample position of each branchline.

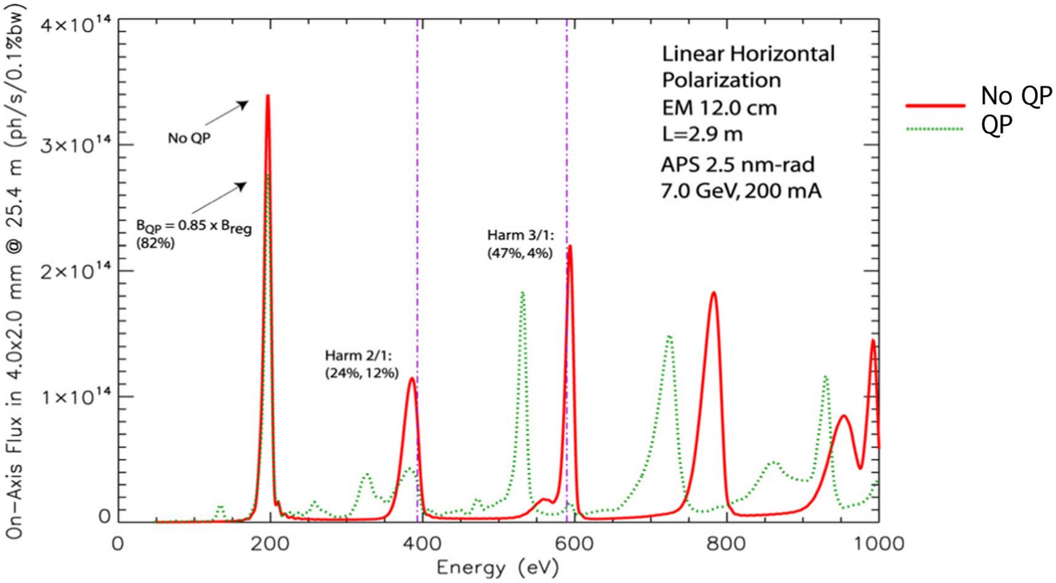


Figure 2. On-axis flux of the fundamental and higher orders light for $h\nu$ = 250 eV is plotted with a fully periodic pole configuration (red) and a 78% quasiperiodic configuration (dashed blue). Running in the quasiperiodic mode significantly reduces the contribution from higher orders greatly improving the signal to noise.

4 Beamline Design

The beamline has been designed to serve two experimental endstations. The first, a "high"-energy (~1000 eV) ARPES system requires very high resolving power (~50,000) and a small spot size at the sample. The second, a RSXS system requires high flux, low beam divergence and moderate resolving power (~2,500). The beamline is optimized for the intermediate energy photon range (250-2500 eV) and will provide 10^{10}-10^{13} photons/sec over that range and at least 10^9 photons/sec between 2,000 and 3,000 eV. Both experimental techniques require good energy reproducibility, low harmonic contamination, highest possible flux, and stability in energy and beam position.

4.1 Beamline Layout

The beamline layout is relatively straight forward and in shown in Appendix B. A APS standard insertion device first optics enclosure (FOE), Sector 29-ID A-hutch, is used and contains the front end optics, two plane mirrors used to absorb the high heat load, beam stops and radiation shielding. A manual bridge mounted trolley chain hoist system with a one-ton capacity has been installed in the A-hutch. Downstream of the FOE, the pink beam with an energy cut off at 3000 eV, is monochromatized via a focusing variable line-spacing plane grating monochromator (In-focus VLS-PGM). The monochromatic beam is then refocused via one of two Kirkpatrick-Baez (KB) optical pairs into either of the experimental chambers. The ARPES branch corresponds to the straight optical path. Inserting the first horizontal refocusing mirrors deflects the beam in the to the RSXS branch. The whole beamline will be windowless, operating under UHV conditions ($< 4 \times 10^{-10}$ Torr) and will be in full compliance with APS vacuum policy including the use of Gamma One ion pumps, Grandville Phillips nude gauges and pumpout ports with convectron gauges and turbos backed by oil free pump. All valves will be purchased from VAT; all-metal type will be used in radiation areas and high use areas. Details of the individual components are in the sections that follow. The beamline is designed by the APS to APS standards. All shutters and endstations will use APS standards for the personnel safety system (PSS) and beamline equipment protection system (BLEPS) as outlined in Section 5.

All beamline components will be surveyed and aligned in place by the APS Survey and Alignment Group. A component list for survey and alignment purposed is included in Appendix E. In order to facilitate the ease of alignment, all components will be referenced via fiducial marks on the mounting assembly using the standard APS survey group flat spots. These flat spots will be easily accessible and be located on the furthest parts of each vacuum chamber for increased accuracy. All components are being designed with a tolerance alignment of ≥ 0.25 mm (20 μrad) and will have at least ± 1.00 (0.5 mm) travel in the horizontal (vertical) for adjustment.

The structure for the beamline utilities including clean, dirty and three-phase electrical power, de-ionized (DI) water supply and return pipes and compressed air supply and return pipes, will be similar to other utility supports at the APS. The beamline utilities locations are shown in the beamline layout (Appendix B). The large span between vertical columns is bridged by I-beams that are bolted to the columns. The utilities will be dropped to the required locations. Two levels of cable trays will span the length of the beamline. Additional cable trays will be mounted to the storage ring inside the A-hutch. Connections to the APS supply transformers will be routed along the top of mezzanine outside wall. The power utility locations are listed in Table 2.

Locations	Clean Power Strips (120 VAC)	Dirty Power Strips (120 VAC)	Dirty 3- Phase Power Outlets (208 VAC)
Inside 29-ID-A	8	8	3
Outside 29-ID-A	2	2	1
Support post	11	11	6
Total	24	24	11

Table 2. Location of electrical power utilities. Each 120 VAC power strip has eight outlets.

The house DI-water will be used for cooling of critical optical components with the exception of the monochromator, which will have a gravity fed water cooling system in order to reduce vibrations,

4.2 Radiation Safety Systems

The beamline primarily employs APS standard components. When needed, modifications to the standard components have been made, and their associated thermal calculations were performed and are attached in Appendix D. The components of the radiation safety system (RSS) are outline in the RSS Component Reference Table (See Appendix D) and are outlined in the following sections.

4.2.1 Supplemental Collimator

The supplemental collimator design is adapted from the design used for the Nanoprobe beam line. The collimator blocks secondary Bremsstrahlung produced by mirrors M0 and M1. The requirements for the shielding are outlined in ANL/APS/TB-21 with a total lead thickness of 50 mm.

4.2.2 White Beam Stop/Pink Beam Mask

Down stream of the supplemental collimator is the white beam stop/pink beam mask. Designed to withstand the full synchrotron beam in the case of mis-steering, the white beam stop prevents any white beam from traveling downstream while allowing the pink beam to pass through. The design has been adapted from the standard APS mask design and is made of water-cooled copper.

4.2.3 Primary Bremsstrahlung Stop

Located downstream of the white beam mask, the primary Bremsstrahlung stop consists of a stack of lead bricks with a total thickness of 300 mm.

4.2.4 Secondary Bremsstrahlung Shielding and Collimators

The secondary Bremshrahlung shielding design consists of tungsten collimators to absorb direct Bremsstrhlung radiation and lead wrapped stainless beampipe to preveng backscatter. The beam pipes located within the FOE and at the exit of the A-Hutch are wrapped in eight complete layers of 0.063 inch thick lead. A ninth layer will be used if sheets are spliced together. The lead, which is free from porosity, oxide, inclusion, fissures and voids, will be coved by a single sheet of rolled aluminum that will then be welded or clamped in place.

4.2.5 Pink Beam Stop

Due to the relative low heat load, this beam stop intercepts the pink beam at normal incidence. The component consists of a stainless steel/copper/stainless flange and is water-cooled in the area of the beam-striking zone.

4.2.6 Monochromatic Beam Shutters

A set of redundant monochromatic beam shutters are located in front of the monochromator exit slit in each branch of the beamline. These shutters are used to allow safe access to components downstream for maintenance. A standard blank conflat flange with an aperture below the centerline for the monochromatic beam will be used. Additional material material is removed on the sides for increased pumping conductance.

4.2.7 Beam Mis-steering Analysis

The motions for the high heat load, side-bounce mirrors, M0 and M1 each are controlled via a hexapod system. A hexapod system consists of six independently controlled struts that are used for precision motion within all six degrees of freedom. Because the six struts move independently in non-orthogonal directions the system does not have hard stops other than that determined by the length of the struts. The control unit is doubly redundant, both the motor controllers and the encoders are independently monitored. If one moves without the other or outside of the soft-limit range, controlled via limit switches, the motors shut off. The range of each of the six struts acts as a hard stop, providing a limit to range motion corresponding to ±7° about the beam axis, ±7° about the horizontal and ±13° about the vertical for both M0 and M1. The total power transmitted is dependent on the angle of incidence and mirror surface material (bare silicon, Au or high density graphite stripes for M0). Taking the worst case, mis-steering of white beam using the Au stripe, the total transmitted power, integrated over all energies, is calculated as a function of incident angle, shown in Figure 3. Two independent power calculations were performed using Shadow/XOP with the IEX insertion device operating with a 200 mA beam current as the source, the details of which are in Appendix D The transmitted power sharply drops off as the mirror angle is increased from grazing. For a 4.5 mm × 4.5 mm beam, the typical integrated power threshold for cooling is 10 Watts, this corresponds to a misalignment of 2.8° for M0. Using ray tracing to model the mis-steered beam, two masks have been designed to intersect the horizontal and vertical mis-steered beam, Mask 1A and Mask 2A, respectively. Upstream of the secondary Bremsstrahlung collimators additional water-cooled masks, labeled Mask 3A, Mask 4A and Mask 5B, act as masks for mis-steered pink beam which is transmitted through Mask 1A and Mask 2A. Detailed drawings of the masks and thermal analysis are presented in Appendix D; ray traces are included in Appendix C. Mis-steering masks are not required for any of the remaining downstream optics since any reflections after M1 have less than 10 Watts power.

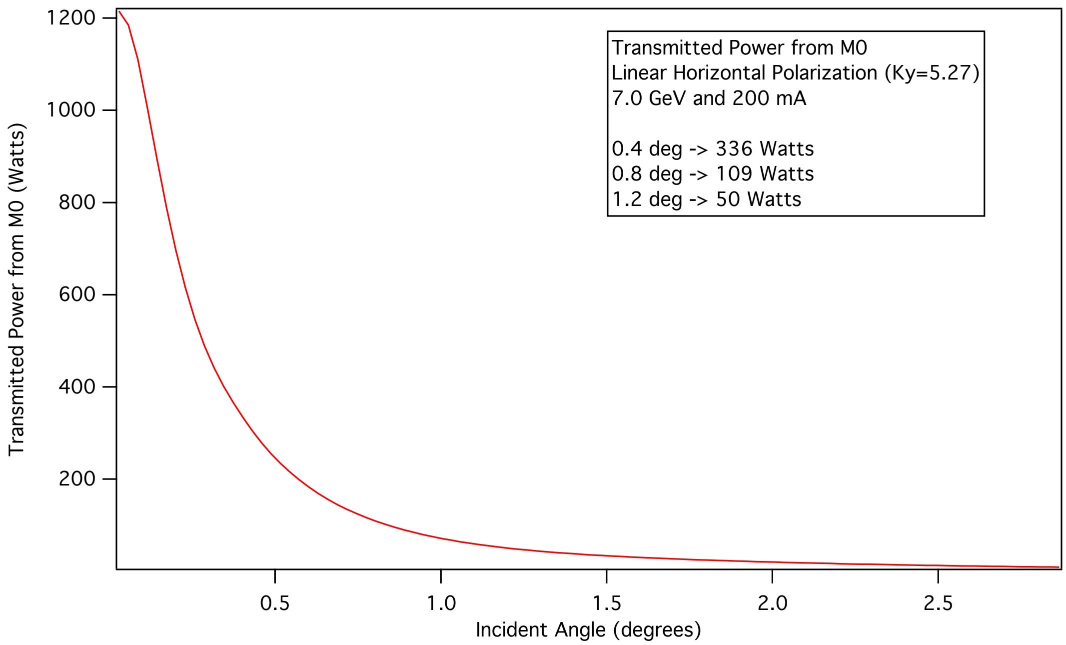


Figure 3. The total power transmitted by M0 as a function of incident/reflected angle.

4.3 Optical Design

A schematic drawing of the beamline showing the two branches is displayed in Figure 4. The beamline will use an APS standard high heat load front end similar to one's used in sectors 30 and 26. The front-end exit table will be housed in the FOE. Due to the various modes of operation of the ID for this beamline, the first pre-mask and the exit mask have been tailored to this beamline. All Bremsstrahlung radiation will be contained inside the FOE. Details of the radiation ray tracing are found in Appendix C.

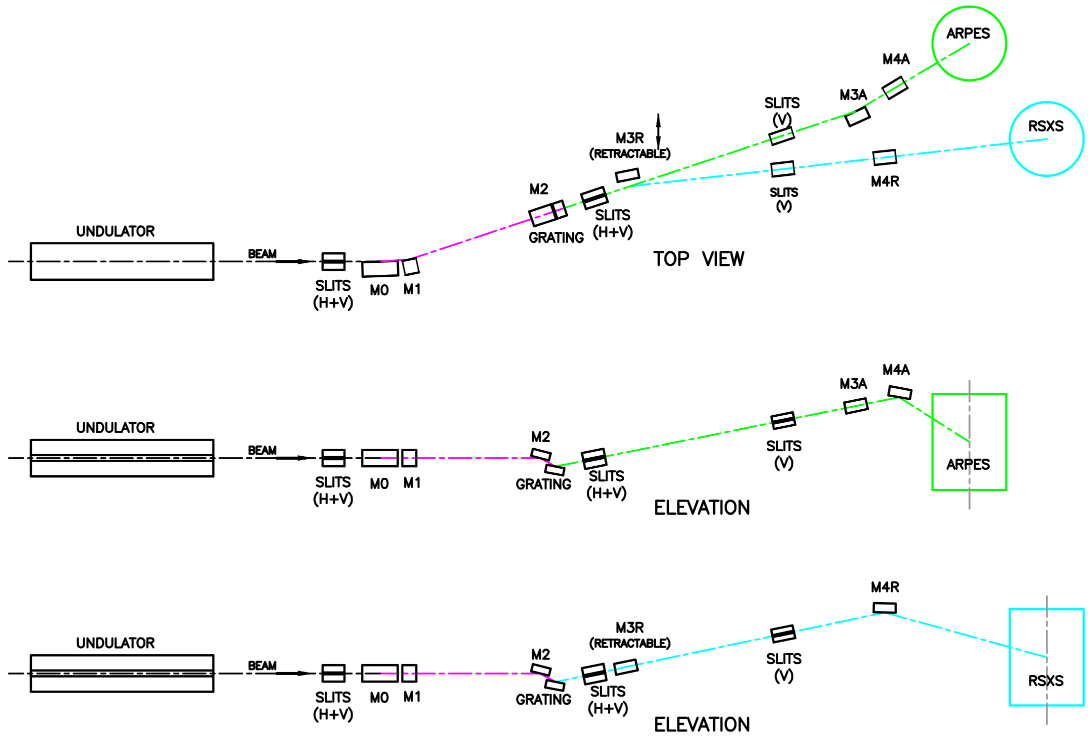


Figure 4. Schematic plan and elevation views of the beamline. Horizontal deflection plane mirrors M0 and M1; vertical deflection plane mirror M2 with grating monochromator; retractable cylindrical horizontally focusing M3R for the RSXS branch; cylindrical vertically focusing M4R for RSXS branch; elliptical cylinders focusing horizontally (M3A) and vertically (M4A) at the sample position of the ARPES branch.

In order to achieve the desired technical specifications, the beamline consists of the following optical elements moving downstream from the shield wall: M0 and M1, which are used to handle the high heat loads produced by the insertion device, a variable line-spacing plane grating monochromator (VLS-PGM), and refocusing KB optics. Each branch line has its own resolution defining vertical slits and refocusing optics. The refocusing is done by a KB pair consisting with of horizontal focusing mirror, M3A(R), and a vertical focusing mirror, M4A(R), for the ARPES(RSXS) branch, respectively. The M3R mirror also serves to deflect the beam into the RSXS branch while the straight through beam goes into the ARPES branch.

The monochromator does not utilize an entrance slit, thereby allowing for higher beamline transmission and the use of planar optical components. The design is an in-focus VLS-PGM based on the Bessy SX-700. It is made up of a plane mirror rotating around an axis not on the mirror surface followed by a grating rotation around its pole. This new generation of plane grating monochromators combined with a stable source should provide the required beam stability and reproducibility. By selecting one of three grating the photon energy, flux and resolving power can be tailored for the specific experiment. A high-resolution grating (HEG), optimized for ARPES experiments provides 10^{10} photons/sec with a resolving power of 50,000 over the 250-2,500 eV range, for a 20 μm exit slit width. The high flux requirements for RSXS are achieved with two gratings both with a resolving power of 2500. The low-energy grating (LEG) produces 10^{13} photons/sec over the 250-2,500 eV range. The medium energy grating (MEG) produces 10^{12} photons/sec for the 250-2500 eV range and 10^{9} photons/sec in the 2500-3000 eV range. Increasing the resolving power of the MEG to 10,000 produces 10^{11} photons/sec over the 250-2,500 eV range.

The position and parameters of the optical elements are given in Table 2. In the sections following, we briefly describe the function of each of the optical components, the relevant equations used in the analytical calculations and their results, as well as ray tracings and flux estimates.

Figure	Distance (m)	Height (mm)	Deflection Angle	Deflection	Size (mm×mm)	Function/Comment
M0: Plane	30.8	0.0	0.8°	Horizontal	520×4	Heat load sink
M1: Plane	31.3	0.0	3.0°	Horizontal	150×4	Heat load sink
Monochromator: M2	39.3-39.6	0.0	0.8°-5.75°	Vertical	80×5	In-focus VLS-PGM
Monochromator: Grating	39.7	-15	1.4°-6.3°	Vertical	75×5	In-focus VLS-PGM
Meridional cylinder: M3R	43.7	40.8	2.5°	Horizontal	200×5	Horizontal focusing
Slit RSXS	59.7	264.0			2×variable	
Meridional cylinder: M4R	64.7	333.8	2.5°	Vertical	70×1	Vertical focusing
RSXS focus	69.7	185.4			0.7×variable	Beam down by 1.7°
Slit ARPES	59.7	264.0			8×variable	
Elliptical cylinder: M3A	64.3	328.5	3°	Horizontal	280×2	Horizontal focusing
Elliptical cylinder: M4A	65.1	339.6	3°	Vertical	65×5	Vertical focusing
APRES focus	66.3	293.5			0.4×variable	Beam down by 2.2°

Table 3. Figure, distance from the source, height above the beam plane, deflection angle, deflection mode, optical size, and function of the optical elements of the two branches (or comment). The optical size for a mirror is length × width and for a cross section is horizontal × vertical. (Values calculated as 4 times the RMS value at 200 eV.)

4.3.1 Mirrors M0 and M1

The first two optical components (M0 and M1) serve as high-heat load components providing power filtering and higher harmonic rejection. As part of the front-end optical design a 4.5 mm × 4.5 mm portion of central synchrotron radiation cone is selected. This photon beam is deflected toward the outboard side via two water-cooled side bounce mirrors, M0 and M1, which deflect the beam by 0.8° and 3.0° respectively, in the horizontal plane. Deflections in the non-dispersive direction take advantage of the small vertical spot size of the source (see Figure 5). This means that the sagittal figure errors of the first mirror, due to manufacturing or heat induced, will be attenuated by the forgiveness factor (i.e., the sine of the grazing angle of incidence on the mirror). However, the figure errors along its meridional direction will affect the horizontal spot size at the sample. The two mirrors are located within the same UHV vacuum chamber as shown in Figure 5. Each mirror is mounted on an independent computer controlled hexapod for alignment purposes. These hexapods are mounted on a granite block to ensure vibrational stability.

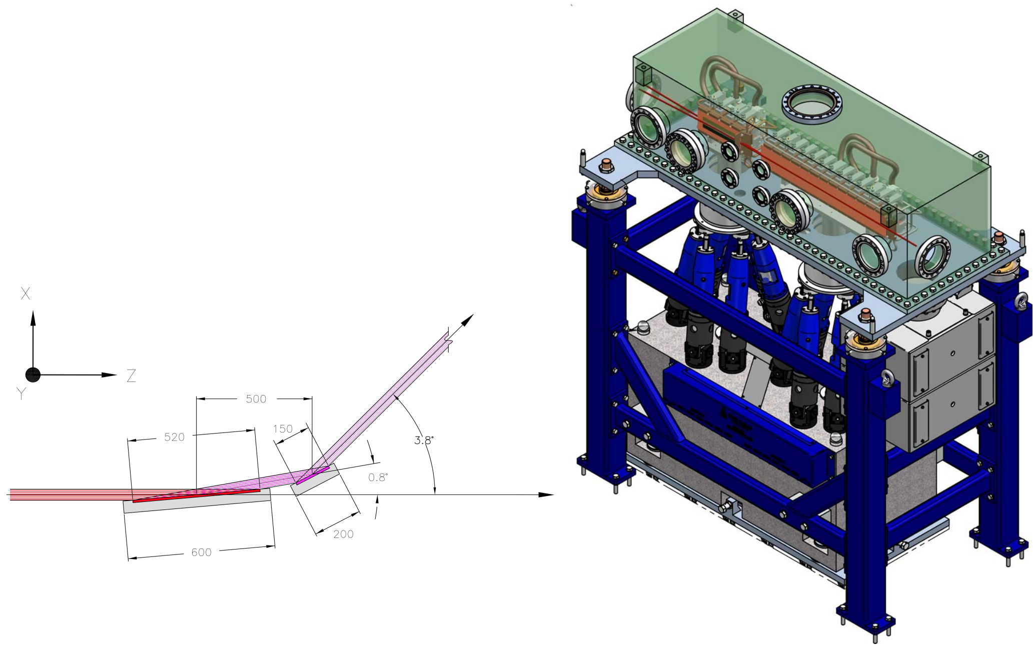


Figure 5. (a) Schematic of the two plane mirrors M0 and M1 used for power absorption. (b) the chamber design for the mirrors, each mirror sits on an independently controlled hexapod used for alignment.

To absorb the power emitted at high photon energies (>3000 eV) by the insertion device when operated in linear mode and high *K* values, the angle of grazing incidence on this mirror should be larger than 1.2°. The resulting power density absorbed by a single plane mirror would be greater than 1.9 W/mm^2. In order to obtain power densities that would not impair the performance of the beamline, we have instead opted to use two plane mirrors to handle the high heat load generated by an insertion device designed for relatively low photon energies in a 7 GeV machine. Each mirror has a small mask to protect the upstream face of each mirror from mis-steered synchrotron radiation beam exposure. These masks are located inside the mirror tank with their shallow edges protruding beyond the upstream edge of the mirror by a few micrometers. They are water cooled and designed to withstand the full SR beam. Additionally, since Compton scattering is a significant source of heat, shielding has been designed to prevent radiation from striking the mirror support, which would resulting in drift and a change in mirror angle.

The highest power density absorbed by M0 is when the insertion device is turned to emit low photon energies, which correspond to high fields. The maximum power density is 0.55 W/mm^2 at 250 eV, corresponding to an absorbed power of 920 W. For M1, the highest power density absorbed is when the ID is turned to emit linear polarized photons at 770 eV. With either the horizontal or the vertical polarization the power density is 0.45 W/mm^2 and the total absorbed power is 280 W. Details of the power load calculations can be found in Appendix F.

Each of the single crystal silicon mirrors will have sufficient vertical travel to allow the selection of a fresh reflecting surface. M0 has an Au coating across the entire optical surface while M1 has both a Au stripe and a high-density graphite in addition to the bare Si surface. For both mirrors all optical coating are 30 nm thick with a RMS roughness < 0.3 nm. The two coatings on M1 are 15 mm wide and run the full length of the mirror. The M0 has a meridional (sagittal) radius $\geq 1\times10^7$ mm ($\geq 3\times10^6$ mm), while M1 meridional (sagittal) $\geq 3\times10^7$ mm ($\geq 3\times10^6$ mm). For both mirrors the slope error $\leq$ 0.5 μrad ($\leq$ 2 μrad). M1 can be fully retracted so that the reflectivity of M0 and degradation can be monitored.

Mask1A has been incorporated into the mirror tank This mask in concert several other masks (Mask 2A, Mask3A, Mask 4A, and Mask5B) act to intercept any mis-steering of either M0 or M1. A full analysis of these RSS components is presented in Section 4.2.7 and in Appendix D.

The reflectivities of all mirrors, assuming an Au coating, were calculated using the optical constants given in the Henke tables such that the reflectivity decreases by the factor $\exp(-(4\pi\eta \cos\theta/\lambda)^2)$, where θ is the angle incidence on the mirror with respect to the surface normal and assuming a RMS roughness $\eta = 0.3$ nm.

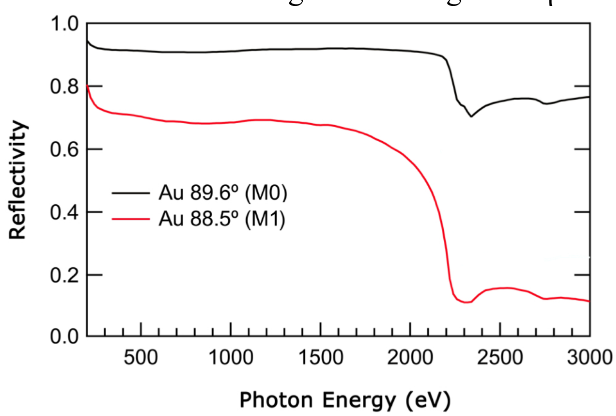


Figure 6. Mirrors reflectivity for M0 (black) and M1 (red) assuming 0.3 nm RMS roughness. In the figure scale the s (vertically polarized light) and p (horizontally polarized light) reflectivities are indistinguishable.

4.3.2 In-focus VLS-PGM

The monochromator is a variable line spacing plane grating monochromator (VLS-PGM) consisting of a vertically reflecting (downward facing) plane mirror, M2, and three separate gratings (upward facing). The assembly which resides within the same UHV vacuum chamber also includes a high-precision, computer-controlled, mechanism to select which of the three grating is to be used and for the independent but simultaneously coordinated motion and rotation of both the plane mirror and the grating. The broad-spectrum "pink" radiation is deflected by M2 onto the grating. After being diffracted off the grating the monochromatic beam is vertically deflected 0.8° upward and is focused on the exit slits. The meridional (sagittal) radius of M2 is $\geq 3\times10^7$ ($\geq 3\times10^6$) with and RMS slope error < 0.2 μrad (< 1.0 μrad).

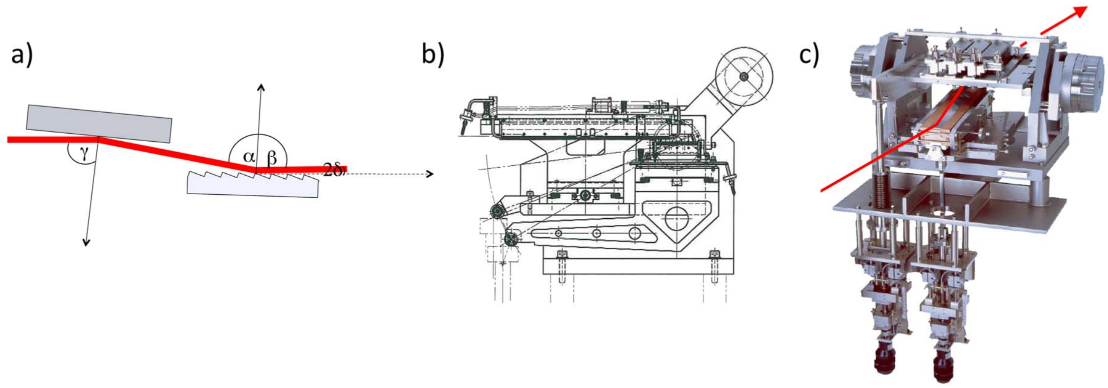


Figure 7. VLS-PGM based on the SX-700 design which uses a plane mirror (M2) to deflect the photon beam onto the grating at the appropriate angle such that the monochromatic beam is focused on a fixed point (the exit slit) for all photon energies. (a) In the schematic the horizontal photon beam (shown in red) is deflected downward by γ onto one of three gratings at an incidence angle of α and is then diffracted by angle β at a take off angle 2δ with respect to the horizontal. (d) a conceptual drawing of the IEX mirror/grating assembly. (c) The CAD drawing shows a similar device with a slightly different geometry (the beam is deflected upward onto one of three gratings).

The in-focus VLS-PGM has the advantage that the beam is focused, at all photon energies, at a fixed exit slit. This focusing is done by using a plane mirror, M2, to deflect the beam downwards (in the dispersion plane) to illuminate the grating at the correct angle of incidence and is accomplished by rotating and translating the mirror. The rotation and translation are actually incorporated in a simple rotation around an axis not on the mirror surface. The angle of incidence on this mirror is given by

$$\gamma = \frac{\alpha - \beta}{2} + \delta \qquad (1)$$

where, α is the incident angle on the grating, β is the diffraction angle (negative) and δ is the take-off angle of the monochromatic beam (δ=0 means that after the grating the selected photon energy is in the horizontal plane). It is advantageous in terms of monochromator efficiency to choose $\delta > 0$ since this increases the angle of incidence on M2 and therefore its reflectivity. This implies that more power and higher orders are transmitted to the grating. Choosing $\delta = 0.4°$ increases the mono efficiency with only a small deviation from the horizontal plane. The beam after the grating has an angle of 2δ relative to the horizontal plane, (0.8° upward).

The reflectivities of M2 when operated with the three selected gratings are shown in Figure 8. Even with $\delta = 0.4°$, the reflectivity of M2 is relatively low. However, the drop in efficiency is a gain in the overall performance of the beamline as this provides better suppression of higher order light and thus a better experimental energy resolution. Coating the single crystal silicon mirror with high density graphite will increase the reflectivity for lower photon energies, $h\nu$ < 1000 eV, except at the carbon K-edge and will suppress higher orders. However, this increase in reflectivity is not sufficient for use with the LEG where low line density means a large angle of incidence of M2 is needed; therefore an Au coating is needed even though it enables the transmission of higher orders. By having two coatings, Au and high-density graphite, we can optimize flux or energy resolution depending on the position on the mirror. Each stripe, the Au coated, the high density coated and the bare Si, will be 10 mm wide and run the full length of the grating. The mirror coatings are 30 nm thick with an RMS roughness < 0.3 nm.

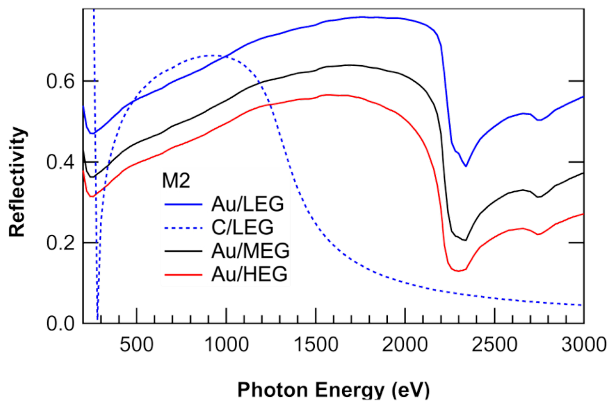


Figure 8. M2 mirror reflectivity with the different gratings, HEG (red), MEG (black) and LEG (blue), and different reflective coatings, Au (solid) and high-density graphite (dashed).

In order to produce the optimal beam parameters for experiments, three separate gratings are being produced. A high-resolution grating (HEG) is used primarily for ARPES. A high flux grating is optimized for the lower photon energies (LEG), while the MEG grating will produce reasonably high flux with "good" resolution and can go to 3000 eV. The line density, k, of each VLS grating along its length, w, is given by

$$k(w) = k_0(1 + 2b_2 w + 3b_3 w^2 + 4b_4 w^3 + ...) \qquad (2)$$

where k_0 is the line density at the grating center, $w = 0$, (w is positive towards the exit slit) b_2 and b_3 are coefficients derived from the defocusing term (f_{20}) and the coma term (f_{30}) in the optical path which are given by

$$f_{20} = \frac{\cos^2\alpha}{dSoGr^2} + \frac{\cos^2\beta}{dGrEx^2} - 2b_2 n k_0 \lambda \qquad (3)$$

and

$$f_{30} = \sin\alpha\frac{\cos^2\alpha}{dSoGr^2} + \sin\beta\frac{\cos^2\beta}{dGrEx^2} - 2b_3 n k_0 \lambda \qquad (4)$$

where α is the angle of incidence on the grating, β is the diffraction angle, dSoGr is the distance from the source to the grating, dGrEx is the distance from the grating to the exit slit, n is the diffraction order, k is the line density of the grating, λ is the wavelength of the light. Table 4 shows the parameters chosen for each grating.

Grating	$c = \frac{\cos\beta}{\cos\alpha}$	k_0 (mm^{-1})	b_2 (mm^{-1})	b_3 (mm^{-3})	Blaze angle
HEG	4.2	2400	0.544×10^{-4}	2.60×10^{-9}	1.6
MEG	2.2	1200	0.695×10^{-4}	2.97×10^{-9}	1.0
LEG	1.5	400	1.100×10^{-4}	4.00×10^{-9}	0.5

Table 4. The grating parameters for the three gratings the high-resolving power grating (HEG), the moderate flux, moderate intensity grating (MEG), and the high flux grating (LEG) are given, where, β is the diffraction angle, and α is the incident of the grating.

By using a plane mirror (M2) upstream of the grating, the grating is illuminated at the optimal incident angle for all wavelengths and the defocusing term goes to zero. The coma term is not identically zero for all wavelengths but is negligible as compared to the other terms determining the resolution of the monochromator. The contributions to the wavelength resolution are due to the vertical source size, the exit slit, and the slope errors of the grating and the plane mirror and are given by

$$\Delta\lambda_{so} = \frac{2.7\ \Sigma_y \cos\alpha}{n\ k\ dSoGr}, \tag{5}$$

$$\Delta\lambda_{ex} = \frac{s\ \cos\beta}{n\ k\ dGrEx}, \tag{6}$$

$$\Delta\lambda_{gr} = \frac{5.4\ \sigma_{gr}}{n\ k}\cos\left(\frac{\alpha+\beta}{2}\right)\cos\left(\frac{\alpha-\beta}{2}\right), \tag{7}$$

$$\Delta\lambda_{pm} = \frac{5.4\ \sigma_{pm}}{n\ k}\cos(\alpha) \tag{8}$$

where, Σ_y is the RMS vertical source size including the electron and photon contributions, s the slit width, and σ_{gr} and σ_{pm} are the RMS meridianal slope errors on the grating and plane mirror, respectively. The sagittal slope errors on the upstream plane mirrors (M0 and M1) also affect the resolution. However, their effect is very small due to the large "forgiveness factor" on these mirrors. Figure 9 shows the resolution components and the total resolution expected for each of the grating.

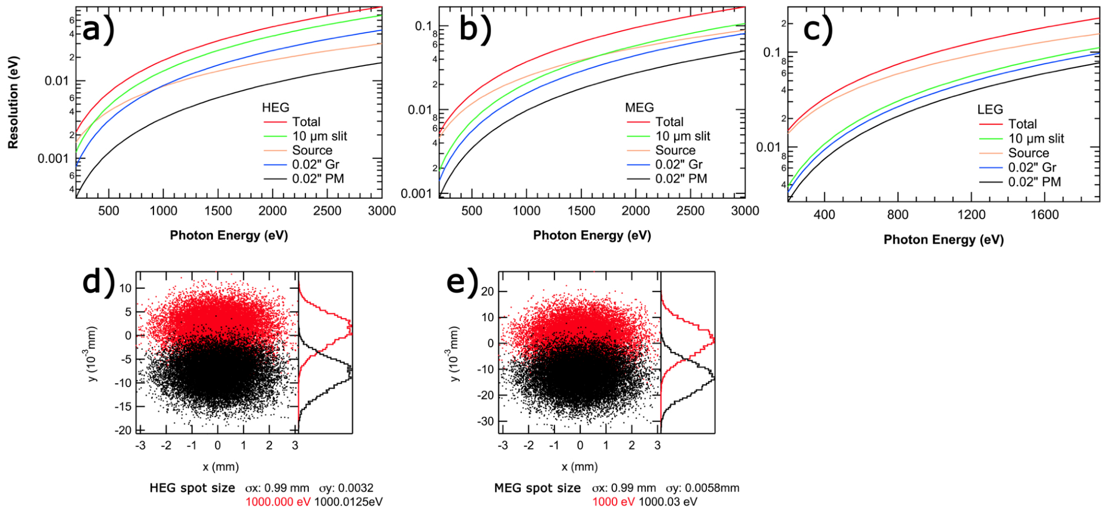


Figure 9. The resolution contribution of the individual optical components, source (gold), the plane mirror, M2, assuming an RMS roughness of 0.02 arcsec (black), the grating due to an RMS roughness of 0.2 arcsec (blue) and a 10 μm exit slit (green) in addition to the total resolution (red) are plotted for (a) the HEG (b) the MEG and (c) the LEG. The ray traces as preformed via the Shadow code are plotted for 1000 eV (black) and 1000.03 eV (red) for (d) the HEG and (e) the MEG.

By zeroing the defocusing term in the optical path the monochromatic beam is focused on the exit slit. The resolution limit of the monochromator, without the exit slit contribution, are verified against ray tracings. The ray tracing was preformed using the Shadow code and included the sample RMS slope errors as the analytical calculations and are shown in Figure 9 (d,e). Note that the Gaussian shape of the ray distributions demonstrates that aberrations are negligible.

The high resolving power required in the ARPES branch can be achieved with a VLS grating having a central line density of 2400 l/mm (HEG) operating at a *c* value (=*cosβ/cosα*) of approximately 4.2°. The calculated contributions to the energy resolution (using Eqs. 5-8) due to the source, RMS slope error of 0.02 arcsec on M2 and the grating, a 10 μm exit slit, and their vector sum are shown in Figure 9 (a). Except at the lowest photon energies, the main contribution to the overall energy resolution is that due to the exit slit width. A resolving power (E/ΔE) higher than 50,000 can be obtained for photon energies up to 1500 eV assuming state of the art (0.02 arcsec) slope errors on the plane mirror and grating and a 10 μm exit slit. Actually, slit widths narrower than 10 μm allow obtaining this high “resolving power” at photon energies higher than 2000 eV. The resolution limit of the monochromator (without the exit slit contribution) with the HEG is 5.2 meV at 500 eV, 12.5 meV at 1000 eV, and 21.6 meV at 1500 eV.

Higher flux and good resolution for ARPES can be obtained with a VLS grating having a central line density of 1200 l/mm (MEG) operating at a *c* value of approximately 2.2°. The resolution terms of this grating as a function of the photon energy are shown in Figure 9 (b). Up to 1500 eV the resolution is dominated by the source size. At higher photon energies the dominant contribution is that of the 10 μm slit. Up to 2000 eV a resolving power on the order of 10,000 can be achieved. The resolution limit of the monochromator, without the exit slit contribution but including the grating, is 30 meV at 1000 eV. This grating is also used for higher energy RSXS experiments (2000-3000 eV) with a resolving power on the order of 2500.

The RSXS experiments require the highest possible flux at moderate resolution, 200 meV up to 1000 eV. For the energy range up to 1900 eV we have chosen a grating with a central line density of 400 l/mm (LEG) operating at a *c* value of approximately 1.5. The resolution terms of this grating are presented in Figure 9 (c). In the figure we show the contribution of a slit width of 10 μm as for the other two gratings. Clearly, to achieve a resolution of 200 eV requires slit widths at least ten times larger than 10 μm. This means that the energy resolution will be dominated by the exit slit width. Therefore, energy dispersion will be present at the sample plane unless the focusing is detuned by selecting a *c* value (the ratio of the cosine of the diffraction angle and cosine of the incident angle) different than the one fulfilling the focusing condition. The cutoff energy of 1900 eV in the figure is due to the length (440 mm) of the optical surface of M2. Higher photon energies required in the RSXS experiments could be achieved with the MEG grating using slit widths of tens of micrometers.

The grating efficiencies were calculated using Neviere's code assuming a Au coating and constant groove densities and are shown in Figure 10 using the parameters listed in Table 4. We included a RMS roughness of 0.3 nm by multiplying the efficiencies by the reflectivity reduction of this roughness on a mirror at the same included angles. The HEG efficiency is higher than 5% between 330 and 1860 eV, the MEG is higher than 12% between 360 and 2140 eV, and the LEG is over 20% over its scanning range.

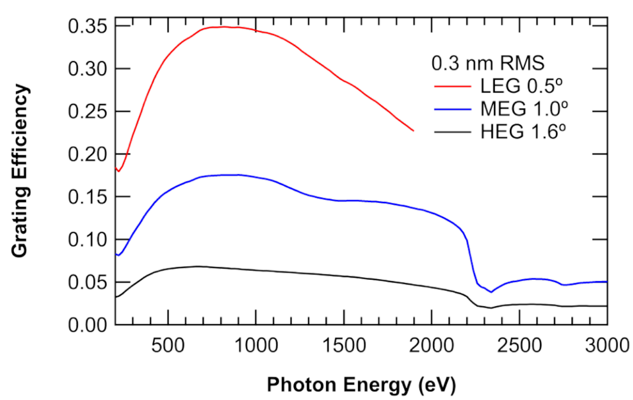


Figure 10. Grating efficiencies for the HEG (black), MEG (blue), and LEG (red) gratings are plotted as function of photon energy, assuming an RMS roughness of 0.3 nm.

The flux after the monochromator as a function of photon energy is plotted in Figure 11. These values were calculated taking into account all the preceding optical components starting with the flux emitted by the insertion device integrated over the central cone, the reflectivity of all mirrors (Figure 11), the grating efficiency and the bandwidth correction for the 10 μm slit. Working with circularly polarized light nearly doubles the flux.

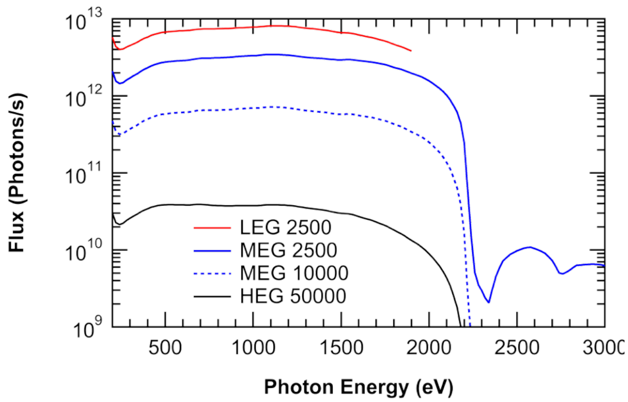


Figure 11. Flux expected at the sample of the ARPES station with the HEG (black), MEG (blue) and LEG (red) are plotted as a function of photon energy with various resolving powers.

To obtain the 50,000 resolving power required for the HEG, the exit slit needs to be 30 μm at 200 eV and 7 μm at 1800 eV. The beamline will deliver almost 2×10^{10} photons/sec in the entire HEG energy range (200 - 2,000 eV). Working with the MEG at a resolving power of 1,000 increases the flux by more than one order of magnitude and requires an exit slit width between 100 and 33 μm for the above mentioned energy range. By going to a lower resolving power 2,500, the MEG will transmit photon energies up to 3000 eV with more than 2×10^9 photons/s (except at the Au M-edges due to the Au coating). The LEG will provide over 4×10^{12} photons/sec at the RSXS sample position over its full energy range (200 – 1900 eV) with a slit width 200 μm at 200 eV and 66 μm at 1900 eV.

The power absorbed in the first four optical elements was calculated with the ID Power routine for several cases. These results were summarized in our report "Power absorbed by the IEX optical elements" dated October 28, 2008 (Appendix F). The power calculations for M0 and M2 were used by Y. Jaski as input for finite element analysis calculations of these mirrors assuming side cooling. Her results for the deformations of M0 and M2 were incorporated in SHADOW to assess whether they can be corrected.

The maximum absorbed power density on M2 is 0.06 W/mm^2 at 384 eV and corresponds to a total absorbed power of 32 W. Figure 12 shows that the deformation due to this absorbed power is enough to increase the vertical size at the exit slit by almost a factor of two. This means that the resolution limit deteriorates by almost the same factor. The original spot size is almost recovered by changing the *c* value from 4.2 to 4.273. A similar correction can be performed with M3 (assuming it is bendable) to the approximately threefold increase in the horizontal spot size at the ARPES station due to the deformation of M0.

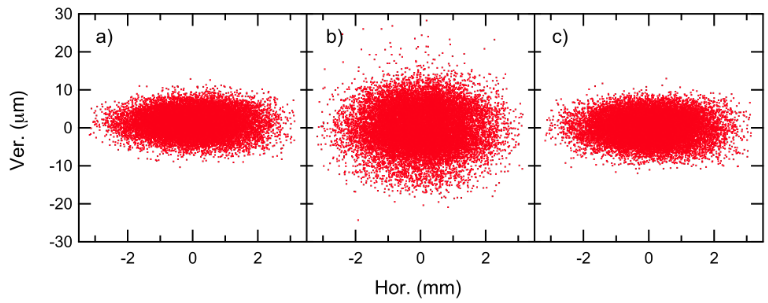


Figure 12. Spot patterns at the exit slit of the ARPES branch for a (a) perfect M2, (b) with slope errors on M2 due to the absorbed power and (c) after correction done by monochromator tuning including slope errors due to heating.

The monochromator tank is equipped with a water-cooled, zero-order beam stop (pink-beam) In the event that mirror M2 is translated out of the direct beam coming from upstream mirror M1, this beam strop intercepts the direct beam and avoids unnecessary heating of the vacuum chamber system. When M2 is in the correct position, this beam stop will intercept any high-energy radiation passing through M2 and again avoiding unnecessary heating of the vacuum chamber.

4.3.3 Refocusing Optics

The requirements for spot size and divergence of the photon beam at the sample position is different for the two types of experiments. A small spot size is required for ARPES measurements while a low beam divergence is more critical for RSXS experiments. Therefore, each branch line has its own refocusing optics in the form of a Kirkpatrick-Baez (KB) optical pair. Both the horizontally focusing mirror (M3A) and the vertically focusing mirror (M4A) are elliptically figured mirrors in the ARPES branch with a demagnification of 31.15:1 and 4.5:1, respectively. The horizontal focusing mirror (M3R) of the RSXS branch also acts to deflect the photon beam horizontally into the RSXS chamber (the straight, undeflected, beam goes to the ARPES branch) while M4R focuses the beam vertically. These nominally planar mirrors provide little demagnification but significantly reduce the beam divergence. The parameters for all four of these Au coated mirrors are outlined in Table 5. Note that the horizontal focusing mirror for the RSXS endstation, M3R is inserted into the beam path to deflect the monochromatic beam into the RSXS end station or is fully retracted to let the monochromatic beam pass into the ARPES endstation.

ARPES branch		**M3A**	**M4A**
Meridional Ellipse			
	semi-major axis	33150 mm	3300mm
	semi-minor axis	296.9 mm	66.64 mm
Sagittal radius		$\geq 3 \times 10^6$ mm	$\geq 3 \times 10^6$ mm
Meridional RMS slope error		$\leq 1.0\mu$rad	$\leq 1.0\mu$rad
Sagittal RMS slope error		$\leq 2.0\mu$rad	$\leq 2.0\mu$rad
Magnification		0.31	0.22
Spot size at sample with $h\nu = 200$ eV and a 10 μm exit slit			
σ_x 1.7 μm			
σ_y 8.9 μm			
RSXS branch		**M3R**	**M4R**
Spherical radius		1.495×10^6 mm	2.292×10^6 mm
Meridional RMS slope error		$\leq 1.0\mu$rad	$\leq 1.0\mu$rad
Sagittal RMS slope error		$\leq 2.0\mu$rad	$\leq 2.0\mu$rad
Magnification		0.6	1
Spot size at sample with $h\nu = 200$ eV and a 100 μm exit slit			
σ_x 170 μm (43 μrad)			
σ_y 30 μm (78 μrad)			

Table 5. The optical parameters are listed for the ARPES horizontal (M3A) and vertical (M4A), and the RSXS horizontal (M3R) and vertical (M4R) refocusing mirrors.

The spot pattern at the sample position for both the ARPES and RSXS branches at 200 eV are shown in Figure 13 with an exit slit width of 10 µm and 100 µm respectively. In addition to the slope errors on the upstream optical elements, the ray tracings include state of the art meridional RMS slope errors equal to 0.1 arcsec on the elliptical cylinder mirrors. As seen in Figure 13 (a), the RMS spot size along the vertical direction is 1.7 µm and 8.9 µm in the vertical direction. The spot pattern at the sample position of the RSXS branch, Figure 13 (b), is 170 µm along the horizontal and 30 µm along the vertical direction. The corresponding spot pattern of the beam divergence is seen in Figure 13 (c). The beam divergence in both directions is significantly less than 300 µrad. Since this case corresponds to the largest divergence, the beam divergence requirements of the RSXS experiments are fulfilled. All optical components are moveable having both in-vacuum translation and rotation for alignment purposes

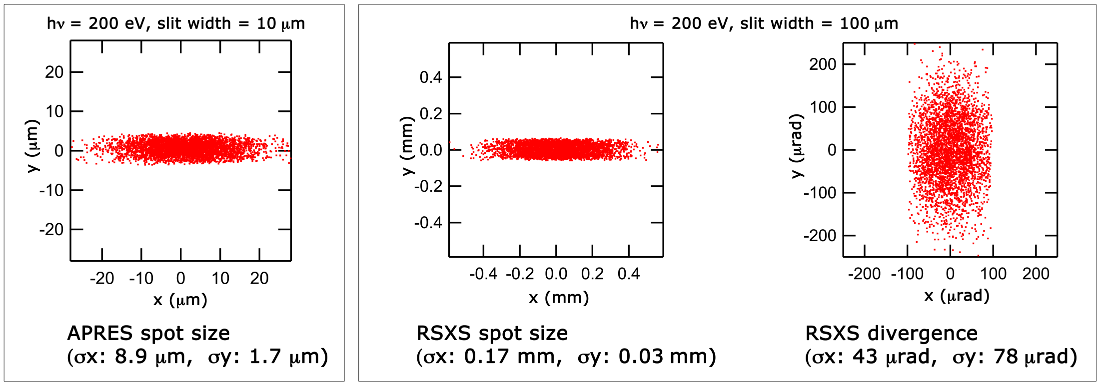


Figure 13. Shadow ray-tracing histograms show the spot pattern at the sample position for 200 eV photons including slope errors at (a) the ARPES station with10 µm slits and (b) the RSXS station with 100 µm slits in mm. The divergence of the RSXS beam at the sample position is shown in (c).

4.3.4 Beamline Diagnostics

For beamline alignment and commissioning we are installing several different slit assemblies and diagnostics chambers that are labeled on the beamline layout. The nomenclature reflects which part of the EPS controls system the diagnostic (D) chambers belong (A for the FOE, B for area downstream of the FOE but upstream of the branch line split, C for the ARPES branch and D for the RSXS branch). The diagnostics are outlined in the schematic layout of the beamline below in Figure 14. Moving downstream from the exit table the first diagnostic system is a set of white beam slits (Slits 1A). These slits are electrically isolated so as to be used for beamline alignment by measuring the photoemitted current, in addition to being used to select a 4.5 mm × 4.5 mm section of the central cone. Also located within the FOE, just downstream of M0/M1 is a wire cross-hairs used for beam position monitoring (D1A) of either white beam or pink beam. Downstream of that we are installing a W mesh (D2A) and DiaGon or similar diagnostic. The photoemission current of the tungsten mesh will be used to track the integrity of both M0 and M1 mirror surface over time. The DiaGon design allows for the imaging of the high flux /high power undulator beam. A specially selected thin film multilayer, inserted into the beam at 45°, acts as an energy filter and diverts the beam to a scintillator with CCD camera. The resulting image is used to determine the actual optic axis and alignment of all apertures upstream of the detector and the presence of higher orders. Additionally, careful analysis of the intensity profile as a function of undulator magnetic fields, allows one to characterize the source including energy dependence, polarization and divergence. The M0/M1 mirror system was designed to allow for the full retraction of M1 enabling beam characterization after deflection by M0 only or after deflection by both M0 and M1. After commissioning this in concert with the mesh will be used to monitor the surface quality of the mirrors.

Downstream of the monochromator is another diagnostics chamber (D3B) followed by another slit assembly (Slit 2B). These horizontal slits, which are used to clean up the photon beam by removing any stray rays, are electrically isolated and can be used as a beam position monitor. The diagnostic chamber contains a YAG crystal will be used as a phosphor screen and a gold mesh for measuring photoemission current. Further characterization of the monochromatic beam, including energy resolution determination, will be done in an in-line photoadsorption gas-cell. Located downstream of the exit slit in the ARPES branch, the gas-cell with utilizes a VAT valve fitted with Luxel filter. These filters can withstand Torr level pressure differential.

In order the ensure that the photon beam is being properly deflected into the RSXS branch by the horizontal deflecting mirror (M3R), a YAG crystal with an etched scale can be inserted into the beam (D4 C/D). In each branch line, just downstream of the monochromatic beam shutters, is YAG crystal (D5C and D5D). Between the last refocusing mirror (M4A/M4R) and the endstation(ARPES/RSXS) in each branchline a final diagnostic chamber (D6C/D6D) sits. Both feature a YAG crystal, gold mesh and an absolute intensity photodiode. The RSXS diagnostic chamber (D6D) will also have several reference samples/standards for energy calibration and a sputter gun for cleaning the references and the Au mesh.

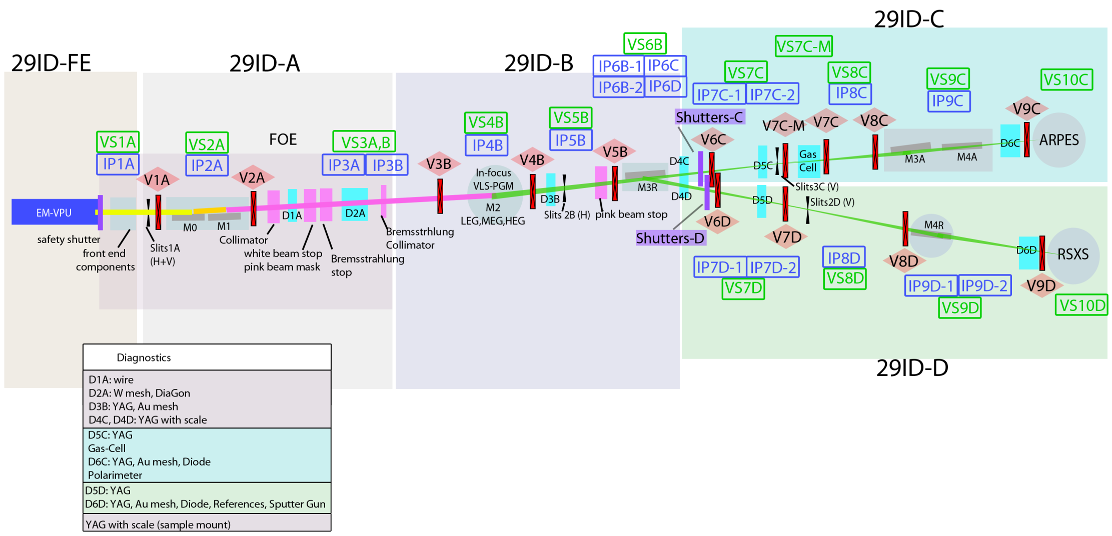


Figure 14. A schematic layout of the beamline and diagnostics.

4.4 Beamline Vacuum Systems

The beamline has been designed in full compliance of the APS vacuum policy. This beamline is window-less and operates under UHV conditions ($< 4 \times 10^{-10}$ Torr). All beamline components are designed to UHV standards. The beamline and the endstations will use Gamma Vacuum ion pumps for vacuum pumps and will use Granville-Phillips nude ion gauges. All gate valves will be APS standard VAT style valves. All metal valves will be used in the FOE and for any frequent use valves. Each valved-off section of the beamline will have an ion pump, an ion gauge and a pump-out section, which consists of a tee or cross with a convectron gauge and angle-valve, to which a turbo cart can be connected. Oil-free roughing pumps back all turbo pumps.

Vacuum valves are to be interlocked with the pressure gauges, ion pumps and temperature components (flow meters and thermocouples) both upstream and downstream of the valve.

The white beam shutter will be interlocked with all valves upstream of the monochromator to protect them from white beam and pink beam exposure. The shutter will not be opened when any valves could possible be exposed to white or pink beam.

Nitrogen gas with suitable over pressure release valves will be used for venting any vacuum component.

4.5 End Stations

4.5.1 ARPES Endstation

The ARPES end station follows previous successful designs. The station will be equipped with a Scienta R4000-WAL 0.1 commercial analyzer shown in Figure 15, which has been developed to work at intermediate (~1000 eV) photon energies to be used in this instrument. A partial view of the sample chamber design is shown in . The analyzer performance characteristics are shown in Table 6 below.

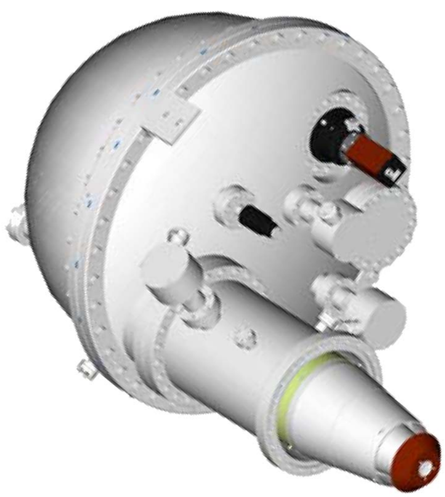


Figure 15. Scienta R4000-WAL 0.1 analyzer has an acceptance angle of ±15° and an energy resolution ~10 meV(at hν = 1000 eV).

The Scienta analyzer has been developed to work at these intermediate (1000 eV) photon energies. The performance characteristics are shown in Table 6.

Pass Energy (eV)	Angular Acceptance	Angular Resolution	Momentum Resolution at $h\nu$= 1 keV	Kinetic Energy (eV)
50	$\pm$ 3.5°	$<$ 0.1°	0.03 $\AA^{-1}$	1000
50	$\pm$ 15°	$<$ 0.4°	0.11 $\AA^{-1}$	1000

Table 6. The performance parameters of the Scienta R4000-WAL 0.1 analyzer are listed.

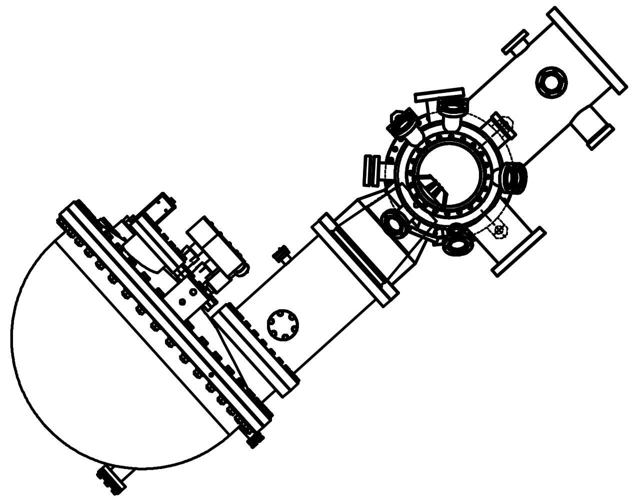


Figure 16The ARPES endstation layout

The vacuum chamber will be made of mu-metal or have a mu-metal insert, in order to minimize magnetic fields. VG-Scienta has decades of experience building such chambers. This vacuum chamber will include a cryogenically cooled shield surrounding the sample, in order to obtain sample temperatures on the order of 1K. This procedure has been demonstrated in the laboratory of S. Shin, at the ISSP, by a former student working with J.C. Campuzano. The sample will be mounted on an Oxford Instruments Heliox V ^{3}He refrigerator, enclosed in a ^{4}He jacket with small sample access, which can cool the sample to <400 mK.

The cross sections for *d* and *f* states of some elements to be studied are reduced by approximately two orders of magnitude at 1000 eV photon energy bring into doubt the feasibility of ARPES measurements at these high photon energies. However, advances in both detector and beamline design overcome the drop in cross-section. Modern electron analyzers are able to multiplex 1000 energy channels in energy. The flux expected from the beamline will be of order 1.2×10^{12} photons/sec at the sample with circularly polarized light (a factor of 2 greater than the linearly polarized light flux) at 40 meV resolution. With these numbers, we can expect a performance similar to that of current experiments at lower photon energies, where beamlines provide 2×10^{11} photons/sec to analyzers that multiplex 256 energy channels, albeit at higher energy resolution. A factor of 10 is gained from the energy multiplexing of the R4000-WAL 0.1 analyzer, and another factor of almost 10 is gained from the very high performance of the beamline. The unusually high performance of the beamline is due to the brilliance of the APS, which allows the entire cross section of the light to traverse a slit width of only 10 μm.

4.5.2 RSXS Endstation

The RSXS system is designed and built by the Abbamonte group at UIUC. This group has a great deal of experience with the design, construction, and operation of vacuum scattering techniques.

The end station has a kappa geometry goniometer and uses a hybrid design of in-vacuum step motors and piezo motors (Fig. 16). The system is based on a large, 1 m diameter, bottom flange with an array of electrical feedthroughs for the stepper motors and detectors. This flange contains an 8" port at the bottom for an 800 l/s turbo pump, which is the main pump for the system, and a port for a titanium sublimation pump, in case extra pumping speed is needed.

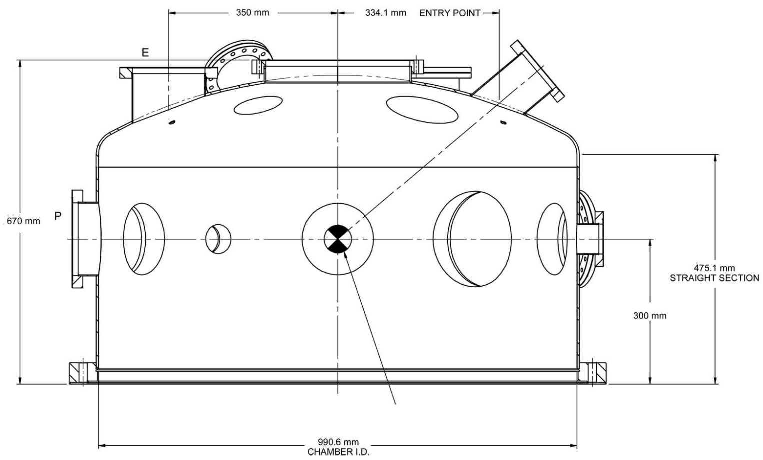
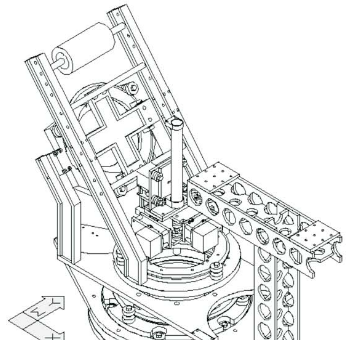


Figure 17 The top bell-jar flange for the RSXS chamber. The bullseye denotes the center of the chamber where the photon beam will be focused.

The “two-theta” (TTH) rotary detector stage resembles a rotating table with threaded holes (like a small optical breadboard) for maximum detector flexibility. This stage has a 360° range horizontal travel, and is mounted on three sets of ceramic bearings to sustain a weight of 30 kg. Actuation is done with in-vacuum step motors using worm drives and several gears to get angular resolution of about ~0.001°. In-vacuum lubricants assure smooth movement.

a)



b)

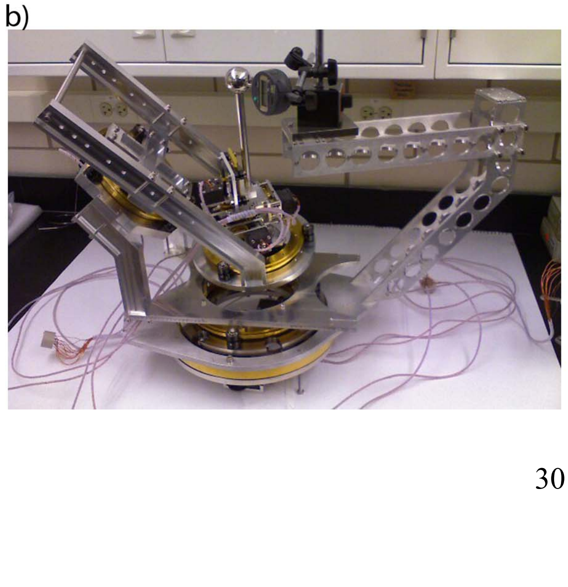


Figure 18. (a) Drawing of the kappa goniometer that forms the core of the RSXS end station. The geometry gives vastly better angular flexibility than standard goniometer designs, with no additional cost. (b) photograph of the actual goniometer.

On the TTH stage are three detectors: A high-sensitivity, single-element, channeltron detector, a position-sensitive channel plate detector, and a photodiode for routine beam alignment. An alternate, energy-resolving configuration is also being constructed, consisting of a backscattering analyzer at the end of the TTH arm, which will likely be a single crystal of Li·$TaSe_2$, and a detector near the sample. The analyzer sits on a piezo stage for angular alignment. The detector stage has the added flexibility of incorporating a polarimeter, though this is not part of the original design.

The vacuum chamber, also 1 m in diameter, will be a "bell-jar" style hoisted from above with a chain come-along. The jar will fit to the bottom flange with a UHV wire seal. Wire seals are old fashioned and somewhat inconvenient to work with but will allow the system to be serviced without dismounting it, which simplifies many other things. Routine maintenance will be carried out through an array of 8" viewports that will be arranged around the side and top of the chamber.

Sample transfer is accomplished with a small sample load lock and two, 35" manipulators. The first is a magnetic manipulator, for transferring samples from the load lock to the main chamber. The second is a rigid, rotary feedthrough for tightening the sample screw. This latter manipulator, which assures tight mechanical contact between the sample and the cryostat, is necessary for achieving low temperature. A sample parking lot is installed in the load lock so that the load lock does not need to be vented at every use.

The sample is cooled with a closed-cycle, He displex cryostat. This system will allow low temperatures (~ 10K, or 20K without radiation shields) to be reached without the trouble, expense, and safety concerns of using liquid cryogens. A vibration isolation stage, placed between the cryostat and the chamber, minimizes vibrations from the expander and ensures that they do not affect the mechanical stages or detectors.

This state-of-the-art system is being produced via commercially available components; the one exception is the Li·$TaSe_2$ backscattering analyzer. This analyzer represents a new approach to soft x-ray energy analysis. To ensure success of the project additional proven analyzers, which can run in both area- and polarimeter- mode, are included in the design.

5 Preliminary Safety Analysis

The beamline conforms to all APS standards. All white beam is contained in the first optical enclosure (FOE). Masks, collimators and radiation shielding have been designed so that only pink beam < 3000 eV exits the FOE. Due to the relative low energy of the beamline, all Bremsstrahlung radiation is contained within the first and only hutch. Ray traces of Bremsstrahlung radiation, horizontal and vertical synchrotron radiation, and optical-apertures are shown in Appendix C. The beamline design is very straightforward As there will be no white beam operations.

5.1 Shielding Designs

The radiation enclosure conforms to the APS standard hutch design and is similar to the FOE designed for Sector 4-ID-A. The IEX beamline radiation enclosure is fixed to and supported by the floor of the Experimental Floor and the walls of the Storage Ring Radiation Containment Tunnel. All shielding panels are manufactured as a steel/lead/steel sandwich. The assembled panels create a structural system capable of supporting the enclosure and attached equipment including the hoist. A one square meter of 50 mm thick supplemental lead shielding panel is located on the downstream panel centered on the white beam. Access to the roof labyrinth is such that the opening will face away from the direction of the beam. Electrical conduit, water piping and air piping will only be routed through specific labyrinths.

The radiation safety interlocks will be designed and installed by the APS. All shielding is compliant to APS standards. The pink beam < 3000 eV does not need additional shielding outside of the FOE since the stainless steel vacuum chamber provides sufficient shielding.

5.2 Personnel Safety System (PSS)

The personal safety system (PSS) is designed and installed by the APS Engineering and Support Division (AES) Safety Interlocks Group (SI). It consists of a three chain Allen Bradley Controllogix programmable logic controller (PLC) system (Gen 3) made up of of two electronic software delivery (ESD) chains and one command and control chain.

The front-end shutters will control access to the FOE. This station is the only white beam area and serves as the only hutch in this soft x-ray beamline. The FOE will have a double door assembly consisting of pneumatically actuated door and a manual door. This allows easy access to the hutch and access for large equipment by opening both doors. Both doors position will be monitored by PSS. Search buttons are positioned by AES/SI to ensure a thorough search is performed before securing the station. Crash buttons, emergency egress buttons strobes and warning speakers are also installed in the station. The PSS will monitor DI-water flows to the beam mis-steering masks (Mask1A and Mask2A), a white beam stop and a pink beam stop. In addition to the controls in the FOE, the two experimental branchlines each have a doubly redundant mono shutters monitored by the PSS. The USER key is used to control the use of the beamline.

5.3 Equipment Protection System (EPS)

The beamline equipment protection system (BLEPS) will also be designed and installed by AES/SI. Using Allen Bradley Controllogix PLCs. The BLEPS will be used to monitor the beamline vaccum via vacuum gauges and ion pumps, and gate valve positionsThe beamline is very long and to isolate pumping sections VAT-UHV viton valves will be used and mounted so that the viton is downstream of the source. Between any two valves there will be an ion pump, vacuum gauge and a pump out port.

In addtion the BLEPS, will monitor the temperature and water flows of the following optical components: M0, M1, M2, gratings and the resolution defining slits Slit3C and Slit3D. Flow rate will be measured with differential pressure flowmeters. M0 and M1 are side cooled with the house DI-water system such that any thermally induced errors are within the parameter specific for each mirror. The temperature of the mirrors and all mirror masks will be monitored via K-type thermocouples and are part of the PLC interlock system. M0 and M1 are masked to protect the upstream face of each mirror from mis-steered synchrotron radiation beam exposure and are designed to withstand the maximum power of the full synchrotron radiation beam. The mirror supports have been designed to minimize exposure to scattered radiation. The Compton scattering is a significant source of heat, which would result in thermal drift of the optical components. The monochromator consisting of a plane mirror, M2, and gratings will be water cooled via a gravity-fed system in order to ensure beam stability. In order to farther protect equipment, piping for DI-water supply and return as well as compressed air supply and return will, whenever possible, be routed along the cable tray support on top of the hutch and spanning the support columns. Inside the hutch these utilities will be routed along the storage ring shield walls out of the way of equipment

All the motors along the beamline will be controlled using EPICS with absolute encoders. Limit switches will be "normally closed". The switches and any hard stops will be accessible so that adjustments can be made.

5.4 Nitrogen and Compressed Air

Conventional APS utility service compressed air will be used for pneumatically operated beamline equipment such as shutters and valves. Additionally, APS dry supply N2 will be used for clean venting and purging of UHV systems. All vent valves will be equipped with suitable overpressure relief valves. As such there are no significant risks associated with these conventional procedures.

5.5 Ozone Mitigation

Ozone concentrations for the IEX beamline will be negligible since there will be no beam (white, pink or monochromatic) outside of a vacuum enclosure. The optical design requires that entire beamline will be under stringent UHV conditions.

5.6 Cryogenic Safety

Both end stations will feature a closed-cycle He cryostat. All the components that are at cryogenic temperatures will be located within the vacuum vessel and therefore pose no significant risks. Any time that liquid cryogens are used the safety issues will be addressed in the Experimental Safety Approval Form.

5.7 Life Safety Code

Sector 29-ID is compliant with Life Safety Code; egress aisles and duck-unders are clearly labeled on the beamline layout in Appendix B. Egress aisles are provided with more than 400 ft obstruction free access to experimental hall main exits. No dead-end pockets greater than 50 ft in length exist. All aisles are approximately 44 inches (1.12 m) in width. Two main egress aisles run alongside the sector beamline, one runs along the in-board side of the RSXS (29ID-D) branch (between sectors 29 and 30) and includes a duck-under exit, the other runs along the out-board side of the ARPES (29ID-C) branch.

5.8 Fire Safety

The designs for the IEX enclosure (29ID-A hutch) and transport do not include significant fire hazards. The policies and procedures for accessing and mitigating any fire hazard in Sector 29 will be addressed in the final IEX Safety documents.

5.9 Other Hazards

Sector 29-ID does not currently plan to use any hazardous chemical, electrical hazards, high-power lasers, biohazards or any other hazards that would impact beamline design.

5.10 Special Operating Requirements

There are no plans at present, which require special operations requirements for Sector 29-ID.

Appendix A. Overview of WBS and Major Milestones

Appendix B. Beamline Layout

Appendix C. IEX Radiation Ray Traces

Synchrotron: White Beam/Pink Beam, Horizontal View
Synchrotron: Vertical View
Bremsstrahlung: Horizontal View
Bremsstrahlung: Vertical View
Secondary Bremsstrahlung
Synchrotron: Monochromatic Beam, Horizontal View
Mis-steering of M0 and M1

Appendix D. IEX RSS Components

- **RSS Component Reference Table**
- **RSS Shielding Calculations**
- **RSS Component Assembly Drawings**
  - **M0 and M1 Beam Mis-steering Masks (WBS: 1.4.3.29.1.6.1)**
    - **Mask1A**
    - **Mask2A**
    - **Mask3A**
    - **Mask4A**
    - **Mask5B**
  - **White Beam Stop/Pink Beam Mask (WBS: 1.4.3.29.1.6.2)**
  - **Primary and Secondary Bremsstrahlung Shielding (WBS: 1.4.3.29.1.6.3)**
    - **Primary Bremsstrahlung Stop**
    - **Supplemental Collimator**
    - **Secondary Bremsstrahlung Collimators 1A**
    - **Secondary Bremsstrahlung Collimators 2A**
    - **Secondary Bremsstrahlung Collimators 3B**
    - **Secondary Bremsstrahlung Shielding-Long**
    - **Secondary Bremsstrahlung Shielding-Short**
    - **Pink Beam Stop (WBS: 1.4.3.29.1.6.4)**
  - **Monochromatic Beam Shutters (WBS: 1.4.3.29.1.6.5)**
- **M0/M1 Beam Mis-steering Report and Thermal Analysis**

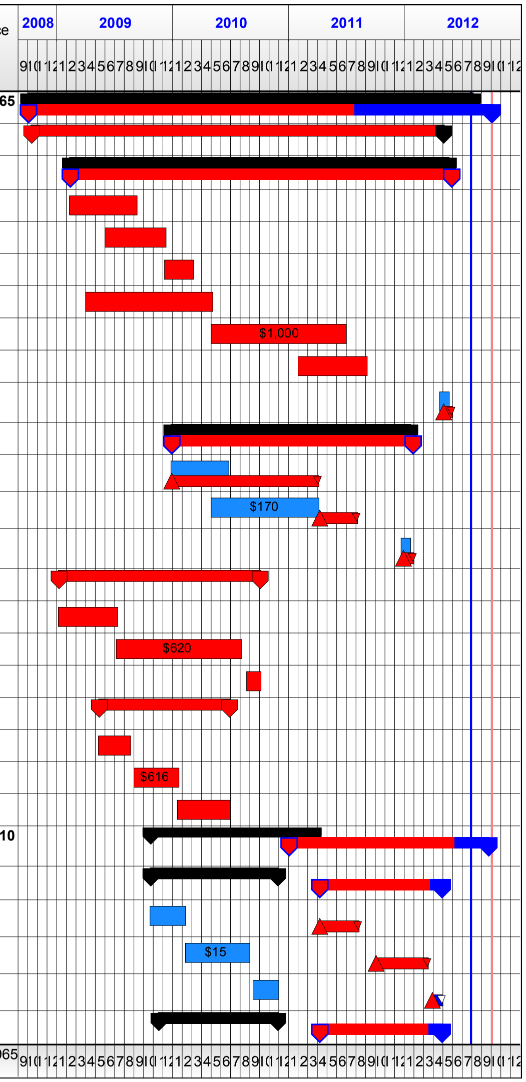
Appendix E. IEX Component Alignment Tolerances

Appendix F. IEX EPS Documents

Power Adsorbed by the IEX Optical Elements
FEA for M0
IEX PSS and EPS Component Tables

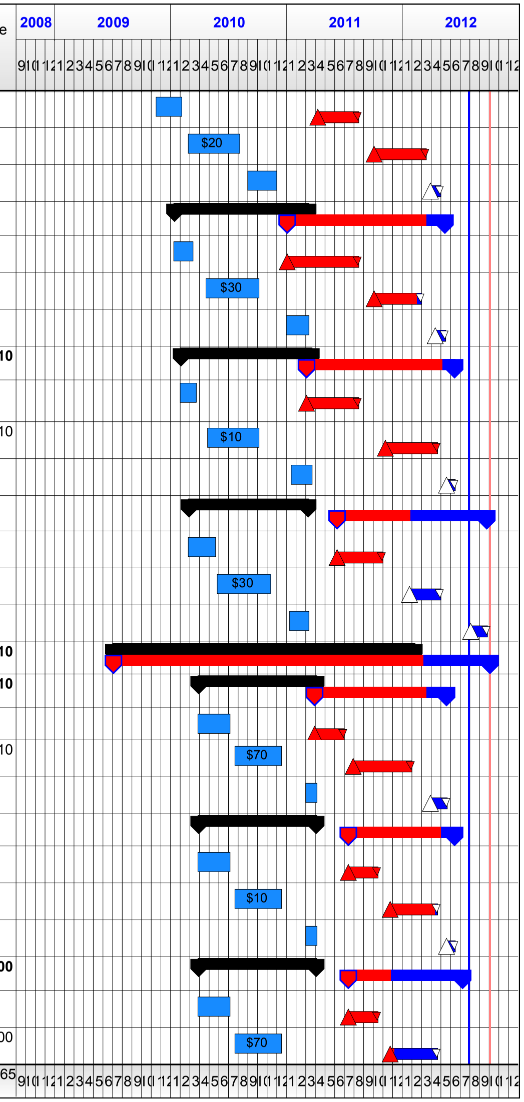
IEX Cost/Schedule

	WBS	Activity Name	Revised Start Date	Revised Finish Date	DOE ($K)	NSF ($K)	Total (2007) ($K)	% Complete	Actuals NSF ($K)	Balance NSF ($K)	Actuals DOE ($K)	Balance DOE ($K)
1	IEX 1.4.3.29.1		**10/1/08**	**9/28/12**			**$8598**	**70.2%**	**2,954.60**	**896.00**	**3,774.00**	**$965**
2	IEX 1.4.3.29.1.1	**Planning...**	**10/13/08**	**4/30/12**				**98.8%**				
11	IEX 1.4.3.29.1.2	**EM Device (Undulator)**	**2/9/09**	**5/28/12**			**$1000**	**100.0%**	**34.00**		**800.00**	
12	IEX 1.4.3.29.1.2.1	Concept	2/9/09	9/4/09				100.0%				
13	IEX 1.4.3.29.1.2.2	Prototype Fabrication	6/1/09	12/4/09				100.0%				
14	IEX 1.4.3.29.1.2.3	Prototype Test	12/7/09	2/26/10				100.0%				
15	IEX 1.4.3.29.1.2.4	Design	3/30/09	4/30/10				100.0%				
16	IEX 1.4.3.29.1.2.5	Procurement	5/3/10	6/24/11	**$1,000**		$1000	100.0%	34.00		800.00	
17	IEX 1.4.3.29.1.2.6	Fabrication & Testing	1/31/11	9/2/11				100.0%				
18	IEX 1.4.3.29.1.2.7	Installation	5/1/12	5/28/12				100.0%				
19	IEX 1.4.3.29.1.3	**ID Vacuum Chamber**	**12/28/09**	**1/24/12**			**$170**	**100.0%**			**170.00**	
20	IEX 1.4.3.29.1.3.1	Design	12/28/09	3/31/11				100.0%				
21	IEX 1.4.3.29.1.3.2	Procurement	4/4/11	7/29/11	**$170**		$170	100.0%			170.00	
22	IEX 1.4.3.29.1.3.3	Installation	12/26/11	1/24/12				100.0%				
23	IEX 1.4.3.29.1.4	**Front End**	**1/5/09**	**9/30/10**			**$620**	**100.0%**			**620.00**	
24	IEX 1.4.3.29.1.4.1	Design	1/5/09	7/3/09				100.0%				
25	IEX 1.4.3.29.1.4.2	Procurement	7/6/09	7/30/10	**$620**		$620	100.0%			620.00	
26	IEX 1.4.3.29.1.4.3	Installation	8/19/10	9/30/10				100.0%				
27	IEX 1.4.3.29.1.5	**White Beam Enclosure**	**5/11/09**	**6/25/10**			**$616**	**100.0%**			**616.00**	
28	IEX 1.4.3.29.1.5.1	Design	5/11/09	8/14/09				100.0%				
29	IEX 1.4.3.29.1.5.2	Procurement	8/31/09	1/15/10	**$616**		$616	100.0%			616.00	
30	IEX 1.4.3.29.1.5.3	Installation	1/18/10	6/25/10				100.0%				
31	IEX 1.4.3.29.1.6	**Radiation Safety System Components**	**1/3/11**	**9/21/12**			**$105**	**82.6%**	**7.30**		**30.00**	**$10**
32	IEX 1.4.3.29.1.6.1	Pink Mis-steered Masks (1A,2A,3A,4A,5B)	**4/4/11**	**4/27/12**			**$15**	**90.2%**	**7.30**		**10.00**	
33	IEX 1.4.3.29.1.6.1.1	Design	4/4/11	8/5/11				100.0%				
34	IEX 1.4.3.29.1.6.1.2	Procurement	10/3/11	3/9/12	**$15**		$15	100.0%	7.30		10.00	
35	IEX 1.4.3.29.1.6.1.3	Installation	3/26/12	4/27/12				10.0%				
36	IEX 1.4.3.29.1.6.2	White Beam Stop, Pink Beam Mask	**4/4/11**	**4/27/12**			**$20**	**89.4%**			**20.00**	
					$4,692	**$3,906**	T: $8598		2,954.60	T: 896.00	3,774.00	T: $965



IEX Cost/Schedule

	WBS	Activity Name	Revised Start Date	Revised Finish Date	DOE ($K)	NSF ($K)	Total (2007) ($K)	% Complete	Actuals NSF ($K)	Balance NSF ($K)	Actuals DOE ($K)	Balance DOE ($K)
37	IEX 1.4.3.29.1.6.2.1	Design	4/4/11	8/12/11				100.0%				
38	IEX 1.4.3.29.1.6.2.2	Procurement	10/3/11	3/9/12	**$20**		$20	100.0%			20.00	
39	IEX 1.4.3.29.1.6.2.3	Installation	3/26/12	4/27/12				0.0%				
40	IEX 1.4.3.29.1.6.3	Bremsstrahlung Stop /Collimators	**1/3/11**	**5/11/12**			**$30**	**87.8%**				
41	IEX 1.4.3.29.1.6.3.1	Design	1/3/11	8/12/11				100.0%				
42	IEX 1.4.3.29.1.6.3.2	Procurement	10/3/11	2/24/12	**$30**		$30	90.0%				
43	IEX 1.4.3.29.1.6.3.3	Installation	4/9/12	5/11/12				0.0%				
44	IEX 1.4.3.29.1.6.4	Pink Beam Stop/Mono Beam Mask	**2/28/11**	**6/8/12**			**$10**	**92.2%**				**$10**
45	IEX 1.4.3.29.1.6.4.1	Design	2/28/11	8/12/11				100.0%				
46	IEX 1.4.3.29.1.6.4.2	Procurement	11/7/11	4/13/12	**$10**		$10	100.0%				$10
47	IEX 1.4.3.29.1.6.4.3	Installation	5/14/12	6/8/12				0.0%				
48	IEX 1.4.3.29.1.6.5	Mono Beam Shutters (C &D)	**6/6/11**	**9/21/12**			**$30**	**48.8%**				
49	IEX 1.4.3.29.1.6.5.1	Design	6/6/11	10/28/11				100.0%				
50	IEX 1.4.3.29.1.6.5.2	Procurement	1/23/12	4/27/12	**$30**		$30	0.0%				
51	IEX 1.4.3.29.1.6.5.3	Installation	7/30/12	9/21/12				0.0%				
52	IEX 1.4.3.29.1.7	**Optics and Diagnostics**	**6/29/09**	**9/28/12**			**$2145**	**82.4%**	**1,048.40**	**230.00**	**871.00**	**$110**
53	IEX 1.4.3.29.1.7.1	Slit, White Beam, H & V (1A)	**3/25/11**	**5/16/12**			**$70**	**84.2%**			**70.00**	**$10**
54	IEX 1.4.3.29.1.7.1.1	Design	3/25/11	6/27/11				100.0%				
55	IEX 1.4.3.29.1.7.1.2	Procurement	7/25/11	1/27/12	**$70**		$70	100.0%			70.00	$10
56	IEX 1.4.3.29.1.7.1.3	Installation	3/26/12	5/16/12				0.0%				
57	IEX 1.4.3.29.1.7.2	Diagnostics, Wire Monitor (D1A)	**7/11/11**	**6/8/12**			**$10**	**86.9%**			**17.00**	
58	IEX 1.4.3.29.1.7.2.1	Design	7/11/11	10/11/11				100.0%				
59	IEX 1.4.3.29.1.7.2.2	Procurement	11/21/11	4/16/12	**$10**		$10	95.0%			17.00	
60	IEX 1.4.3.29.1.7.2.3	Installation	5/14/12	6/8/12				0.0%				
61	IEX 1.4.3.29.1.7.3	Diagnostics, DiagOn (D2A)	**7/11/11**	**7/4/12**			**$70**	**36.8%**				**$100**
62	IEX 1.4.3.29.1.7.3.1	Design	7/11/11	10/11/11				100.0%				
63	IEX 1.4.3.29.1.7.3.2	Procurement	11/21/11	4/16/12	**$70**		$70	10.0%				$100
					$4,692	**$3,906**	T: $8598		2,954.60	T: 896.00	3,774.00	T: $965



IEX Cost/Schedule

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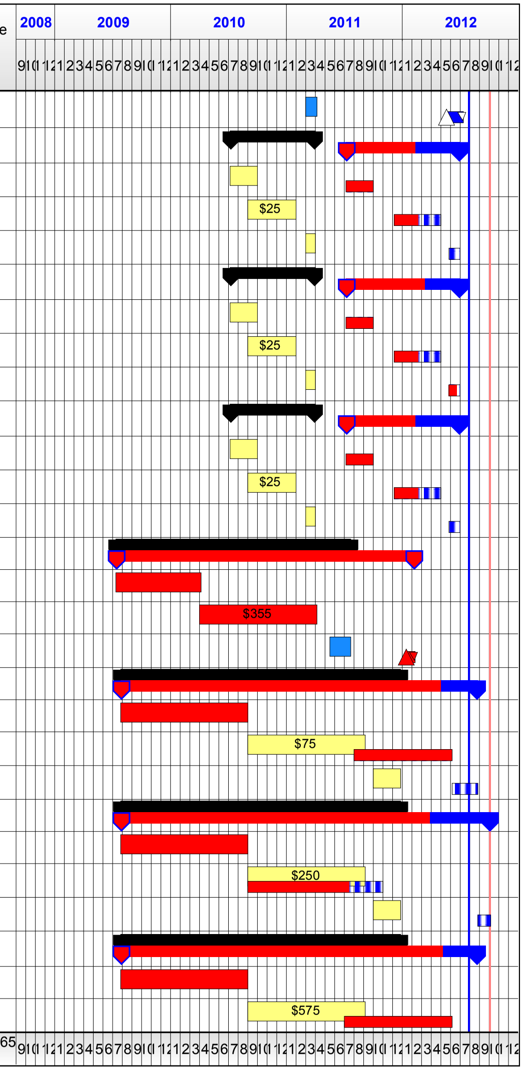
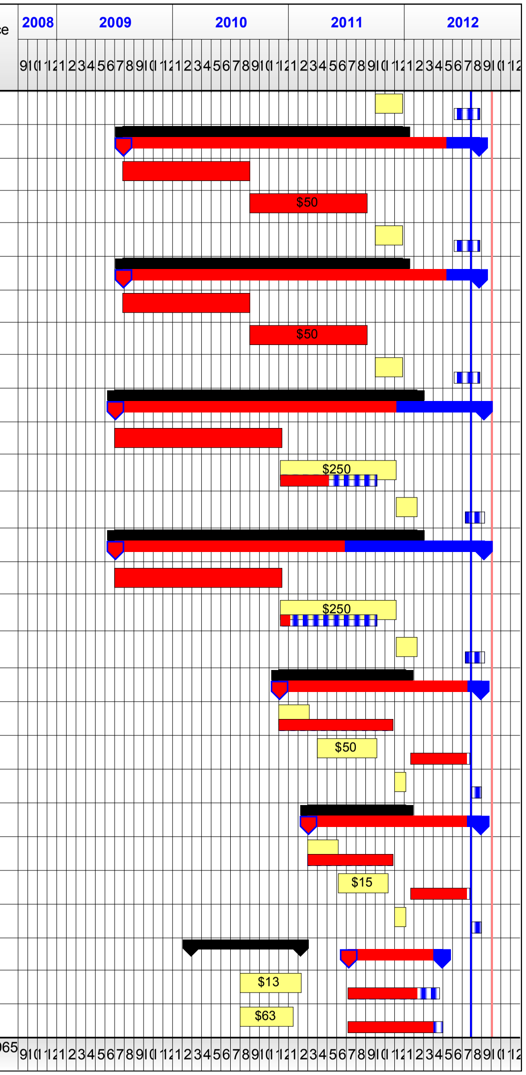
64	IEX 1.4.3.29.1.7.3.3	Installation	5/14/12	7/4/12				0.0%				
65	IEX 1.4.3.29.1.7.4	Slit, Mono Beam, 2B	**7/5/11**	**6/25/12**			**$25**	**60.5%**	**44.00**			
66	IEX 1.4.3.29.1.7.4.1	Design	7/5/11	9/26/11				100.0%				
67	IEX 1.4.3.29.1.7.4.2	Procurement	12/5/11	4/27/12		**$25**	$25	50.0%	44.00			
68	IEX 1.4.3.29.1.7.4.3	Installation	5/28/12	6/25/12				0.0%				
69	IEX 1.4.3.29.1.7.5	Slit, Mono Beam, 3C	**7/5/11**	**6/25/12**			**$25**	**69.0%**	**28.20**			
70	IEX 1.4.3.29.1.7.5.1	Design	7/5/11	9/26/11				100.0%				
71	IEX 1.4.3.29.1.7.5.2	Procurement	12/5/11	4/27/12		**$25**	$25	50.0%	28.20			
72	IEX 1.4.3.29.1.7.5.3	Installation	5/28/12	6/25/12				75.0%				
73	IEX 1.4.3.29.1.7.6	Slit, Mono Beam, 3D	**7/5/11**	**6/25/12**			**$25**	**60.5%**	**28.20**			
74	IEX 1.4.3.29.1.7.6.1	Design	7/5/11	9/26/11				100.0%				
75	IEX 1.4.3.29.1.7.6.2	Procurement	12/5/11	4/27/12		**$25**	$25	50.0%	28.20			
76	IEX 1.4.3.29.1.7.6.3	Installation	5/28/12	6/25/12				0.0%				
77	IEX 1.4.3.29.1.7.7	Mirror, Plane 0,1	**7/13/09**	**2/7/12**			**$355**	**100.0%**			**355.00**	
78	IEX 1.4.3.29.1.7.7.1	Design Specifications	7/13/09	4/2/10				100.0%				
79	IEX 1.4.3.29.1.7.7.2	Procurement	4/1/10	4/1/11	**$355**		$355	100.0%			355.00	
80	IEX 1.4.3.29.1.7.7.3	Installation	1/9/12	2/7/12				100.0%				
81	IEX 1.4.3.29.1.7.8	Mirror, Plane 2	**7/27/09**	**8/20/12**			**$75**	**90.0%**			**94.00**	
82	IEX 1.4.3.29.1.7.8.1	Design Specifications	7/27/09	8/26/10				100.0%				
83	IEX 1.4.3.29.1.7.8.2	Procurement	8/1/11	6/1/12		**$75**	$75	100.0%			94.00	
84	IEX 1.4.3.29.1.7.8.3	Installation	6/4/12	8/20/12				0.0%				
85	IEX 1.4.3.29.1.7.9	Gratings	**7/27/09**	**9/28/12**			**$250**	**83.5%**	**58.00**	**0.00**	**185.00**	
86	IEX 1.4.3.29.1.7.9.1	Design Specifications	7/27/09	8/26/10				100.0%				
87	IEX 1.4.3.29.1.7.9.2	Procurement	9/1/10	10/28/11	**$40**	**$210**	$250	75.0%	58.00	0.00	185.00	
88	IEX 1.4.3.29.1.7.9.3	Installation	8/27/12	9/28/12				0.0%				
89	IEX 1.4.3.29.1.7.10	Grating Mono Housing	**7/27/09**	**8/20/12**			**$575**	**90.4%**	**575.00**			
90	IEX 1.4.3.29.1.7.10.1	Design Specifications	7/27/09	8/26/10				100.0%				
91	IEX 1.4.3.29.1.7.10.2	Procurement	6/30/11	5/31/12		**$575**	$575	100.0%	575.00			
					$4,692	**$3,906**	T: $8598		2,954.60	T: 896.00	3,774.00	T: $965



IEX Cost/Schedule

	WBS	Activity Name	Revised Start Date	Revised Finish Date	DOE ($K)	NSF ($K)	Total (2007) ($K)	% Complete	Actuals NSF ($K)	Balance NSF ($K)	Actuals DOE ($K)	Balance DOE ($K)
92	IEX 1.4.3.29.1.7.10.3	Installation	6/4/12	8/20/12				0.0%				
93	IEX 1.4.3.29.1.7.11	Mirror, Spherical 3R & 4R	**7/27/09**	**8/20/12**			**$50**	**90.7%**	**42.00**			
94	IEX 1.4.3.29.1.7.11.1	Design Specifications	7/27/09	8/26/10				100.0%				
95	IEX 1.4.3.29.1.7.11.2	Procurement	9/1/10	9/2/11		**$50**	$50	100.0%	42.00			
96	IEX 1.4.3.29.1.7.11.3	Installation	6/4/12	8/20/12				0.0%				
97	IEX 1.4.3.29.1.7.12	Mirror, KB 3A & 4A	**7/27/09**	**8/20/12**			**$50**	**90.7%**	**94.00**			
98	IEX 1.4.3.29.1.7.12.1	Design Specifications	7/27/09	8/26/10				100.0%				
99	IEX 1.4.3.29.1.7.12.2	Procurement	9/1/10	9/2/11		**$50**	$50	100.0%	94.00			
100	IEX 1.4.3.29.1.7.12.3	Installation	6/4/12	8/20/12				0.0%				
101	IEX 1.4.3.29.1.7.13	Mirror Hosuing 3R & 4R	**6/29/09**	**9/7/12**			**$250**	**76.0%**	**40.00**	**60.00**	**150.00**	
102	IEX 1.4.3.29.1.7.13.1	Design Specifications	6/29/09	12/3/10				100.0%				
103	IEX 1.4.3.29.1.7.13.2	Procurement	12/6/10	9/30/11		**$250**	$250	50.0%	40.00	60.00	150.00	
104	IEX 1.4.3.29.1.7.13.3	Installation	7/9/12	9/7/12				0.0%				
105	IEX 1.4.3.29.1.7.14	Mirror Housing 3A & 4A	**6/29/09**	**9/7/12**			**$250**	**62.4%**	**80.00**	**170.00**		
106	IEX 1.4.3.29.1.7.14.1	Design Specifications	6/29/09	12/3/10				100.0%				
107	IEX 1.4.3.29.1.7.14.2	Procurement	12/6/10	9/30/11		**$250**	$250	10.0%	80.00	170.00		
108	IEX 1.4.3.29.1.7.14.3	Installation	7/9/12	9/7/12				0.0%				
109	IEX 1.4.3.29.1.7.15	Beam Position Monitors (YAG,mesh,Diode)	**12/1/10**	**8/27/12**			**$50**	**93.2%**	**47.00**			
110	IEX 1.4.3.29.1.7.15.1	Design	12/1/10	11/21/11				100.0%				
111	IEX 1.4.3.29.1.7.15.2	Procurement	1/23/12	7/19/12		**$50**	$50	95.0%	47.00			
112	IEX 1.4.3.29.1.7.15.3	Installation	7/30/12	8/27/12				0.0%				
113	IEX 1.4.3.29.1.7.16	Diagnostics Monitors (gas Cell)	**3/3/11**	**8/27/12**			**$15**	**91.9%**	**12.00**			
114	IEX 1.4.3.29.1.7.16.1	Design	3/3/11	11/21/11				100.0%				
115	IEX 1.4.3.29.1.7.16.2	Procurement	1/23/12	7/20/12		**$15**	$15	95.0%	12.00			
116	IEX 1.4.3.29.1.7.16.3	Installation	7/30/12	8/27/12				0.0%				
117	IEX 1.4.3.29.1.8	**Vacuum**	**7/5/11**	**4/27/12**			**$487**	**89.7%**	**383.60**	**38.00**	**59.00**	
118	IEX 1.4.3.29.1.8.1	Transport pipes	7/5/11	4/13/12		**$13**	$13	75.0%		13.00		
119	IEX 1.4.3.29.1.8.2	Bellows	7/5/11	4/27/12		**$63**	$63	90.0%	24.00	20.00		
					$4,692	**$3,906**	T: $8598		2,954.60	T: 896.00	3,774.00	T: $965

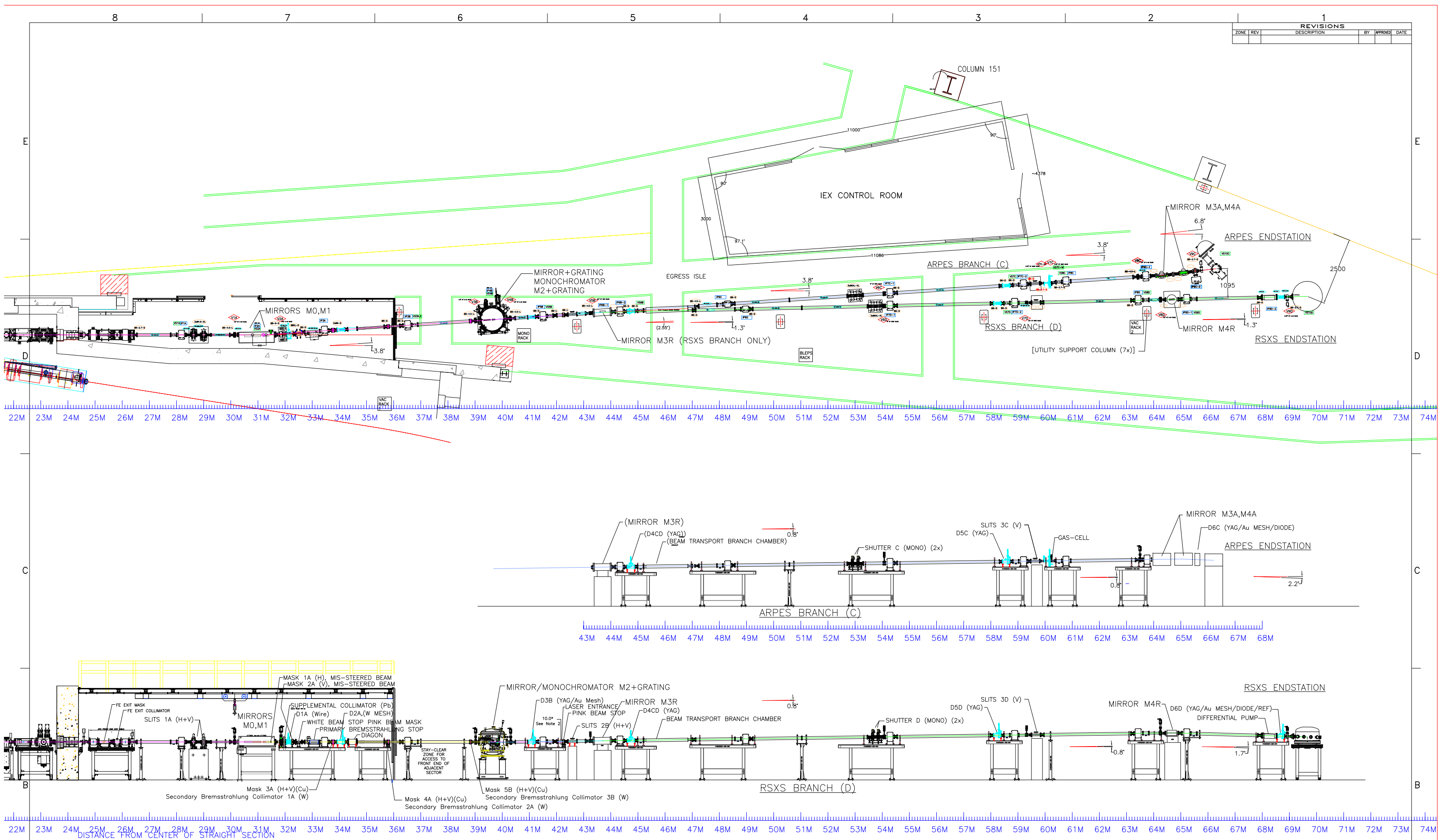


IEX Cost/Schedule

	WBS	Activity Name	Revised Start Date	Revised Finish Date	DOE ($K)	NSF ($K)	Total (2007) ($K)	% Complete	Actuals NSF ($K)	Balance NSF ($K)	Actuals DOE ($K)	Balance DOE ($K)
120	IEX 1.4.3.29.1.8.3	Valves, Gate	7/5/11	1/27/12	**$70**		$70	100.0%	105.00			
121	IEX 1.4.3.29.1.8.4	Valves, Angle	7/5/11	1/27/12	**$10**		$10	100.0%	14.00			
122	IEX 1.4.3.29.1.8.5	Ion Pumps, Controller, Cables	7/11/11	1/27/12	**$140**		$140	95.0%	124.30			
123	IEX 1.4.3.29.1.8.6	RGA	9/5/11	11/25/11	**$10**		$10	75.0%	48.00			
124	IEX 1.4.3.29.1.8.7	Pump Ports	9/12/11	1/27/12	**$6**		$6	100.0%			7.00	
125	IEX 1.4.3.29.1.8.8	Vacuum Monitors, Cables	7/11/11	1/27/12	**$65**		$65	100.0%			52.00	
126	IEX 1.4.3.29.1.8.9	Turbo Pump Station	10/10/11	2/24/12		**$50**	$50	100.0%	31.00			
127	IEX 1.4.3.29.1.8.10	Differential Pump	11/7/11	3/30/12		**$25**	$25	50.0%	26.00			
128	IEX 1.4.3.29.1.8.11	Gaskets, Flanges, Viewports, Bolts, Tools	9/5/11	1/27/12	**$35**		$35	95.0%	11.30	5.00		
129	IEX 1.4.3.29.1.9	**Supports, Hardware etc.**	**1/3/11**	**1/27/12**			**$90**	**82.6%**	**31.30**	**17.00**		**$5**
130	IEX 1.4.3.29.1.9.1	Beamline components table	1/3/11	1/27/12		**$50**	$50	95.0%	25.30			
131	IEX 1.4.3.29.1.9.2	Steel, Column	1/3/11	1/27/12		**$30**	$30	100.0%	6.00	7.00		
132	IEX 1.4.3.29.1.9.3	Mounting Hardware	2/7/11	1/27/12		**$10**	$10	50.0%		10.00		$5
133	IEX 1.4.3.29.1.10	**Sample Stations**	**10/1/10**	**7/9/12**			**$1300**	**70.0%**	**1,150.00**	**150.00**		
134	IEX 1.4.3.29.1.10.1	ARPES...	10/1/10	7/9/12		**$650**	$650	50.0%	500.00	150.00		
150	IEX 1.4.3.29.1.10.2	RSXS Station 650 ...	1/3/11	5/31/12		**$650**	$650	95.0%	650.00			
169	IEX 1.4.3.29.1.11	**Survey and Alignment**	1/9/12	9/28/12			$0	15.0%				
170	IEX 1.4.3.29.1.12	**Computers/Controls**	**5/10/10**	**10/28/11**			**$160**	**87.1%**	**81.00**	**19.00**	**60.00**	
171	IEX 1.4.3.29.1.12.1	Computers/network	5/10/10	2/25/11	**$60**		$60	100.0%			60.00	
172	IEX 1.4.3.29.1.12.2	Controls	5/10/10	10/28/11		**$100**	$100	80.0%	81.00	19.00		
173	IEX 1.4.3.29.1.13	**PSS/EPS**	1/25/11	6/8/12	**$110**		$110	85.0%			90.00	$15
174	IEX 1.4.3.29.1.14	**Utilities**	3/17/09	3/7/11	**$70**		$70	75.0%			20.00	$25
175	IEX 1.4.3.29.1.15	**Sample Preparation Enclosure**	10/3/11	8/31/12	**$150**		$150	15.0%				$150
176	IEX 1.4.3.29.1.16	**Rigging**	1/12/10	5/2/12	**$5**		$5	40.0%			5.00	$15
177	IEX 1.4.3.29.1.17	**Materials and Supplies**	**2/23/10**	**6/22/12**			**$75**	**62.5%**	**18.00**	**40.00**	**121.00**	**$170**
178	IEX 1.4.3.29.1.17.1	M&S	2/23/10	6/22/12	**$50**		$50	50.0%			40.00	$170
179	IEX 1.4.3.29.1.17.2	M&S	2/23/10	6/22/12		**$25**	$25	75.0%	18.00	40.00	81.00	
180	IEX 1.4.3.29.1.18	**Post Doctoral Associates/ Student**	3/22/10	3/20/12		**$130**	$130	100.0%	130.00			
181	IEX 1.4.3.29.1.19	**Travel**	10/1/08	7/31/12	**$25**		$25	50.0%			15.00	$15
					$4,692	**$3,906**	T: $8598		2,954.60	T: 896.00	3,774.00	T: $965

IEX Cost/Schedule

	WBS	Activity Name	Revised Start Date	Revised Finish Date	DOE ($K)	NSF ($K)	Total (2007) ($K)	% Complete	Actuals NSF ($K)	Balance NSF ($K)	Actuals DOE ($K)	Balance DOE ($K)	2008 2009 2010 2011 2012
182	IEX 1.4.3.29.1.20	**Miscellaneous (Drafting, Freight &Shops...)**	4/20/09	4/27/12		**$70**	$70	30.0%	3.00			$20	$70
183	IEX 1.4.3.29.1.21	**Overhead (10%) $400K DOE Funds only $50K UIC (Non-Instrumentation)**	10/1/08	7/31/12	**$400**	**$50**	$450	75.0%	68.00	12.00	297.00	$0	$450
184	IEX 1.4.3.29.1.22	**Contingency (DOE 10%- $430K, NSF 10%-$390K)**	**10/23/08**	**8/1/12**			**$820**	**0.0%**		**390.00**		**$430**	
185	IEX 1.4.3.29.1.22.1	DOE Contingency	10/23/08	7/30/12	**$430**		$430	0.0%				$430	$430
186	IEX 1.4.3.29.1.22.2	NSF Contingency	10/27/08	8/1/12		**$390**	$390	0.0%		390.00			$390
					$4,692	**$3,906**	T: $8598		2,954.60	T: 896.00	3,774.00	T: $965	



Notes:

1) Caution:
Vacuum forces produced by in-line bellows can be in access of several hundred pounds. They can easily move heavy components unless they are properly secured to the floor! Before any vacuum pump-down on sections or the entire beamline, appropriate mounting configuration for each component must be veryfied and if necessary corrected. Only after it is confirmed that all components are safely bolted to prevent shifting, vacuum pump-down may begin.

2) The vertical distance between the center of the pink beam stop FLANGE (bottom of the aperture) to the center of the white/pink beam is 10 mm, provided the pink beam stop is located at 11111±20 mm from the secondary source.

3) M0 M1 chamber is rotated 0.8 degrees from the white beam centerline.

4) Due to the change of separation between M0 and M1, the beam center lines have been moved. The revised location starts at 31.3m from the source.
The distance between the mirrors changed from 800mm to 500mm. M0 moved 300mm downstream, and M1 remained at the same distance to the source (Z=31.3mm), but it moved inboard by −4.18906243mm (X).
The shift effects both brances and all components downstream of the first 2 mirrors.

5) Due to the multiple projection angles of the individual beamline branches, this drawing does not represent the exact location of the optics. Refer to the survey and alignment sheet for the exact mirror, slit and end chamber locations.

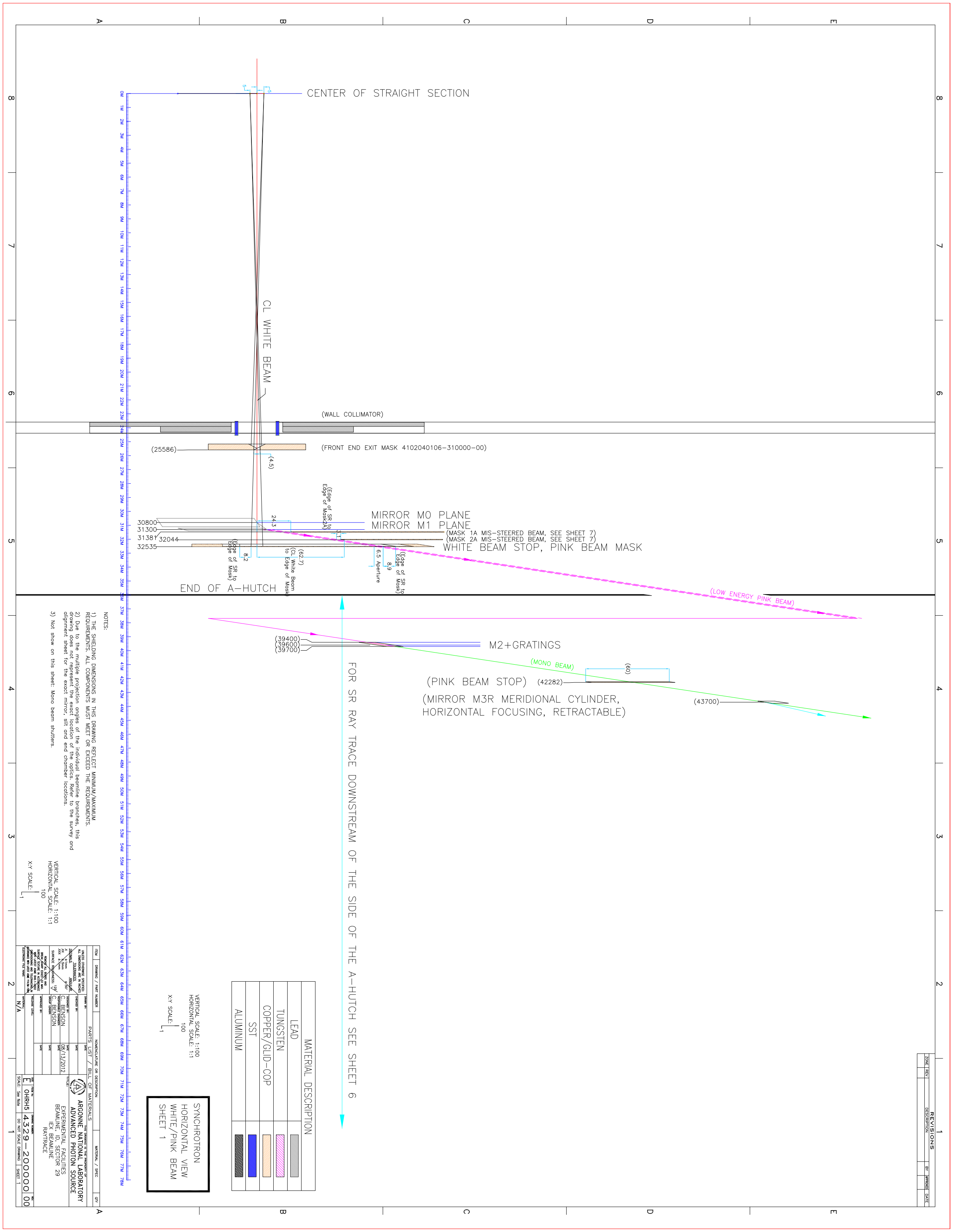
PARTS LIST / BILL OF MATERIALS

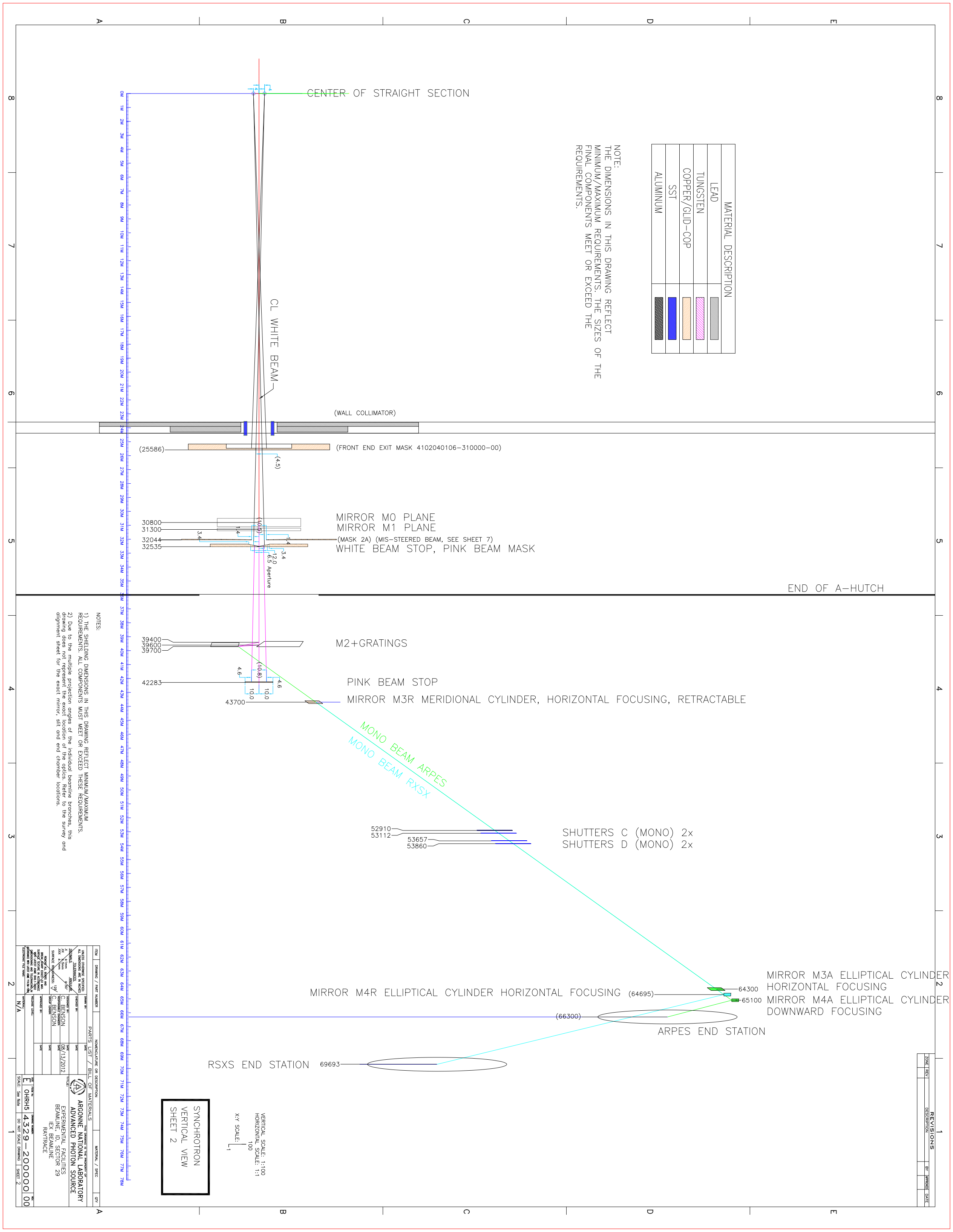
ARGONNE NATIONAL LABORATORY
ADVANCED PHOTON SOURCE

EXPERIMENTAL FACILITIES
BEAMLINE, ID, SECTOR 29
IEX BEAMLINE
LAYOUT

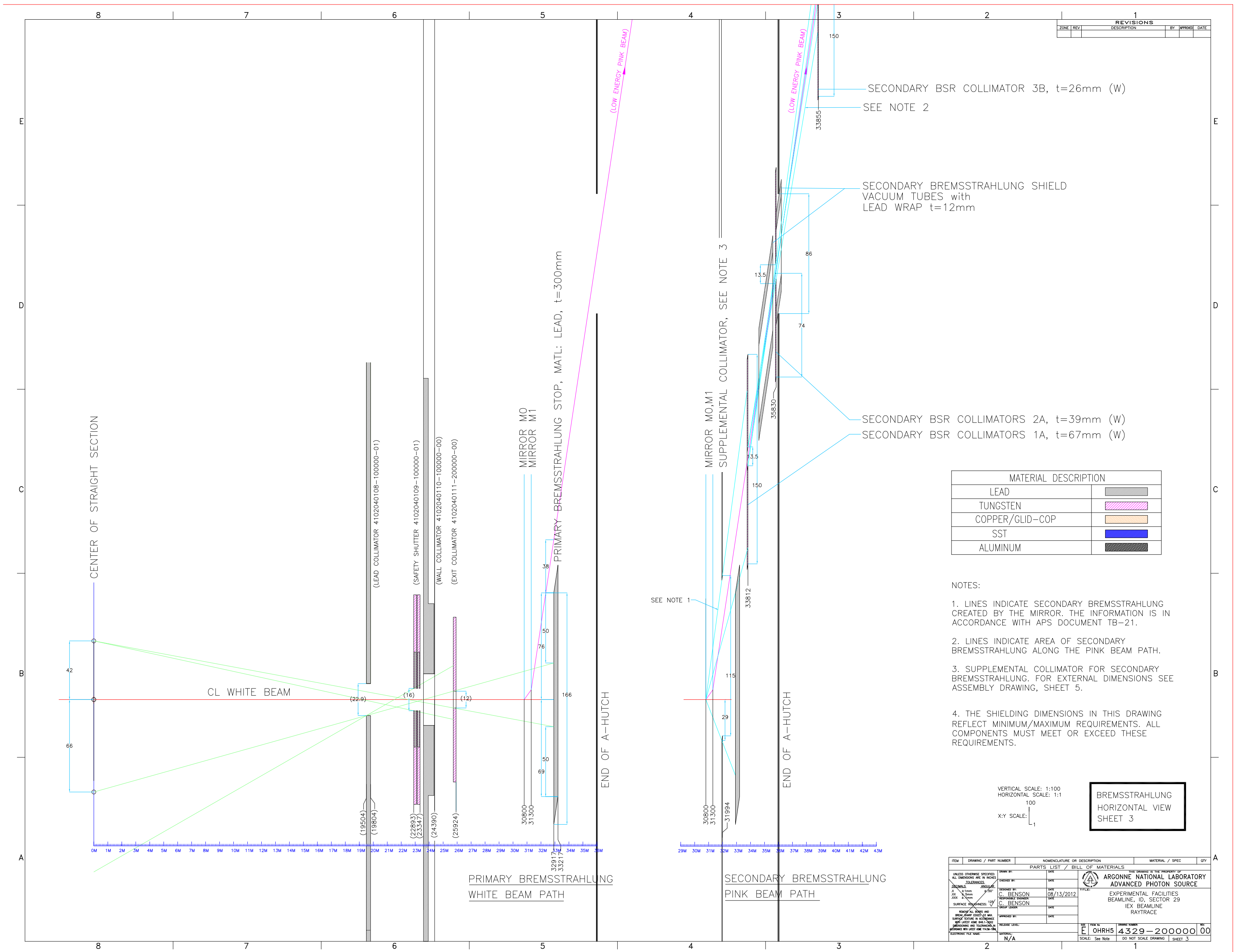
DESIGNED BY: C. BENSON 08/13/2012

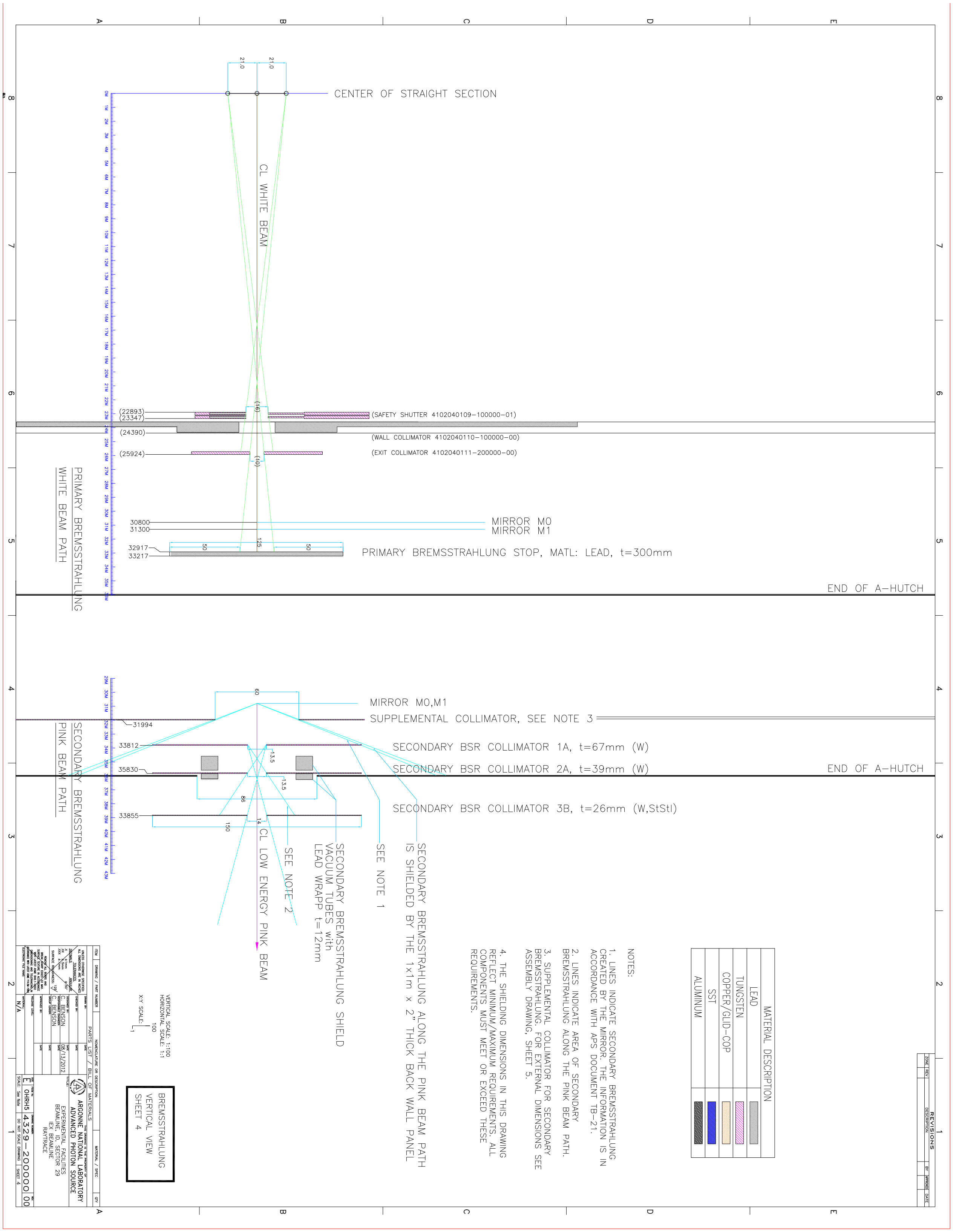
E OHRH5 4329−200000 00

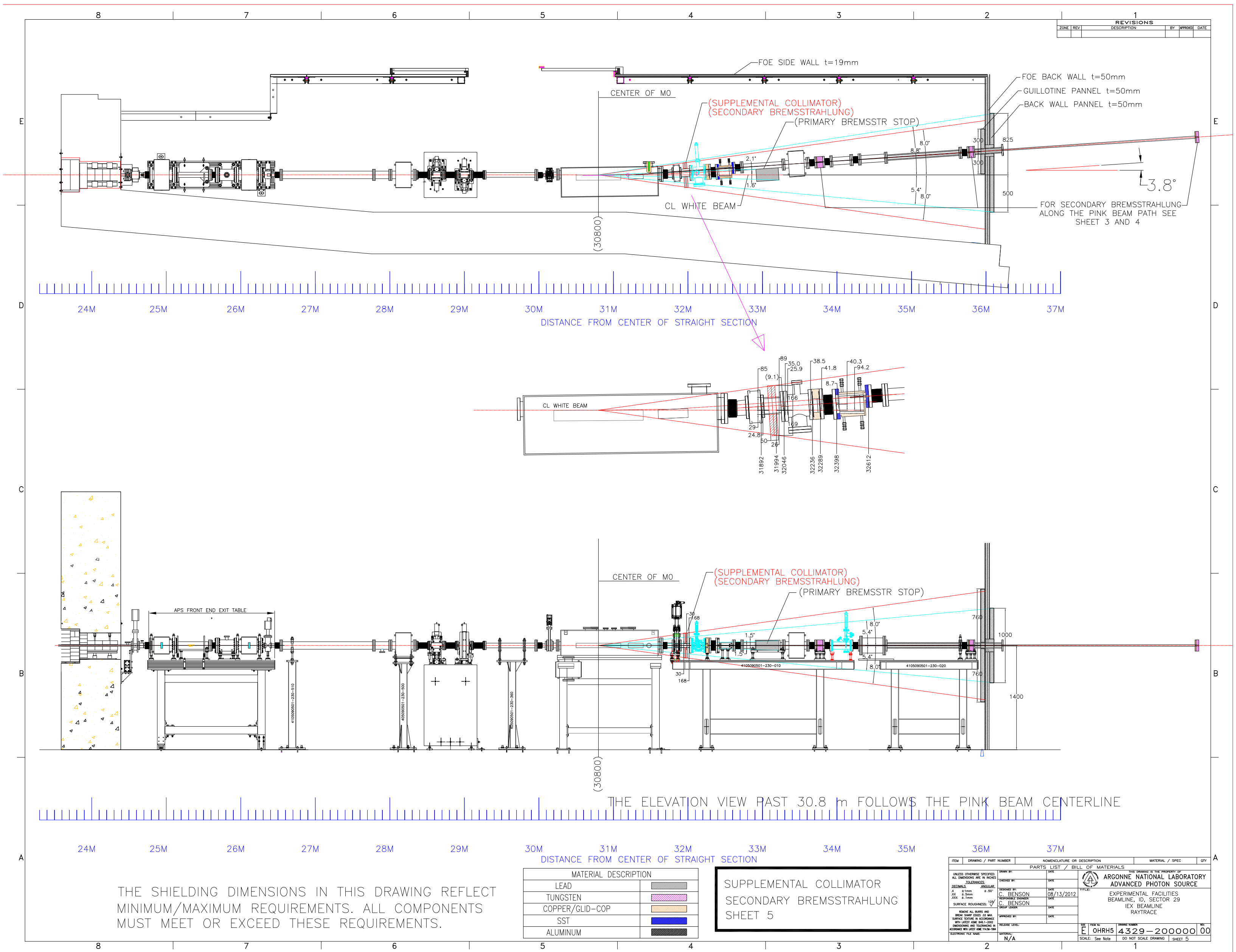

CENTER OF STRAIGHT SECTION
CL WHITE BEAM
(WALL COLLIMATOR)
(25586)
(FRONT END EXIT MASK 4102040106-310000-00)
(4.5)
MIRROR M0 PLANE
MIRROR M1 PLANE
(MASK 1A MIS-STEERED BEAM, SEE SHEET 7)
(MASK 2A MIS-STEERED BEAM, SEE SHEET 7)
WHITE BEAM STOP, PINK BEAM MASK
30800
31300
31381
32044
32535
24.3
8.2
(62.7)
6.5 Aperture
8.9
END OF A-HUTCH
(LOW ENERGY PINK BEAM)
(39400)
(39600)
(39700)
M2+GRATINGS
(MONO BEAM)
(60)
(PINK BEAM STOP)
(42282)
(MIRROR M3R MERIDIONAL CYLINDER, HORIZONTAL FOCUSING, RETRACTABLE)
(43700)
FOR SR RAY TRACE DOWNSTREAM OF THE SIDE OF THE A-HUTCH SEE SHEET 6
NOTES:
1) THE SHIELDING DIMENSIONS IN THIS DRAWING REFLECT MINIMUM/MAXIMUM REQUIREMENTS. ALL COMPONENTS MUST MEET OR EXCEED THE REQUIREMENTS.
2) Due to the multiple projection angles of the individual beamline branches, this drawing does not represent the exact location of the optics. Refer to the survey and alignment sheet for the exact mirror, slit and end chamber locations.
3) Not show on this sheet: Mono beam shutters.
VERTICAL SCALE: 1:100
HORIZONTAL SCALE: 1:1
MATERIAL DESCRIPTION
LEAD
TUNGSTEN
COPPER/GLID-COP
SST
ALUMINUM
SYNCHROTRON
HORIZONTAL VIEW
WHITE/PINK BEAM
SHEET 1
REVISIONS
ARGONNE NATIONAL LABORATORY
ADVANCED PHOTON SOURCE
EXPERIMENTAL FACILITIES
BEAMLINE ID, SECTOR 29
IEX BEAMLINE
RAYTRACE
E
OHRHS
4329-200000
00
N/A



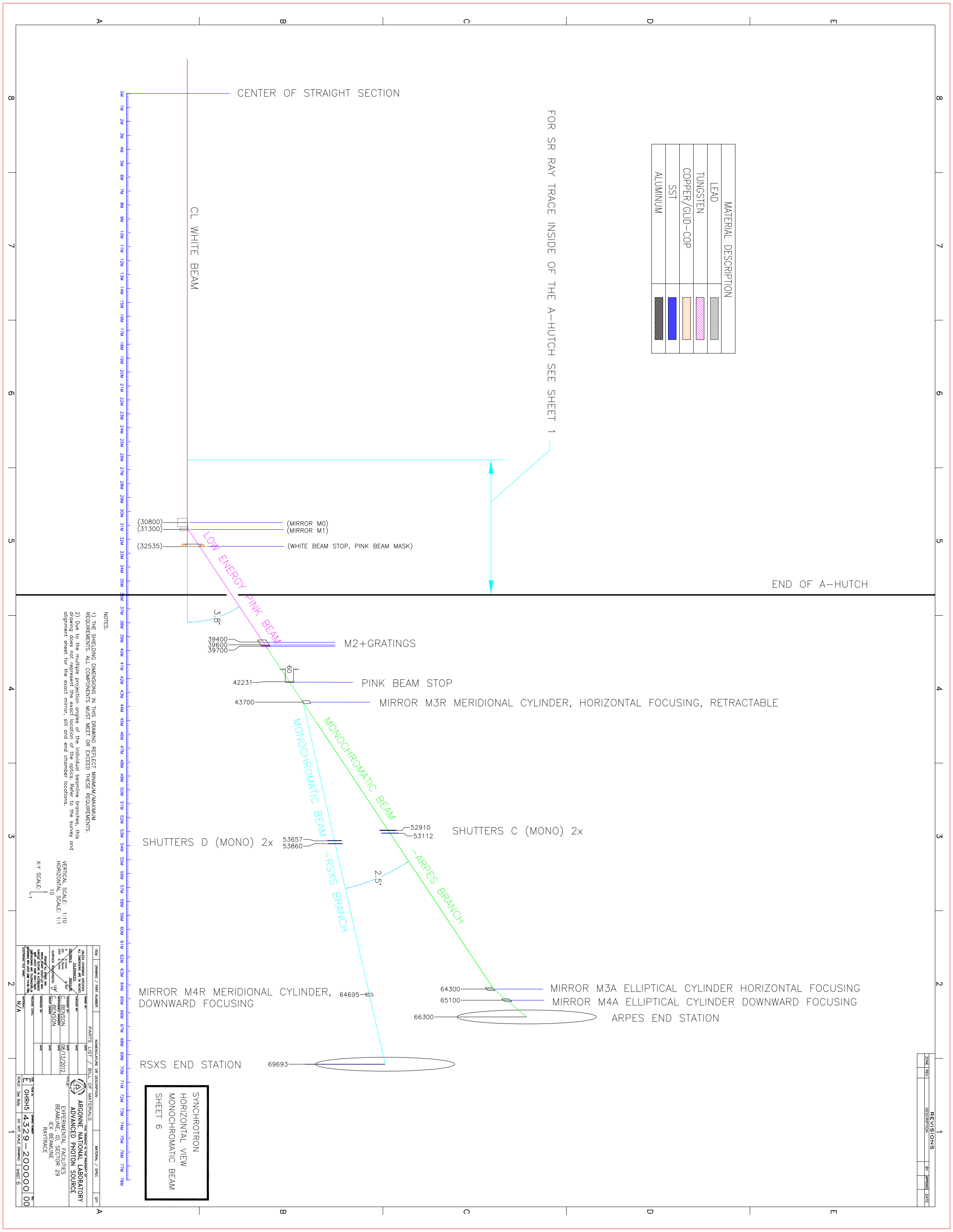
CENTER OF STRAIGHT SECTION
CL WHITE BEAM
MATERIAL DESCRIPTION
LEAD
TUNGSTEN
COPPER/GLID-COP
SST
ALUMINUM
NOTE:
THE DIMENSIONS IN THIS DRAWING REFLECT MINIMUM/MAXIMUM REQUIREMENTS. THE SIZES OF THE FINAL COMPONENTS MEET OR EXCEED THE REQUIREMENTS.
(WALL COLLIMATOR)
(25586)
(FRONT END EXIT MASK 4102040106-310000-00)
30800
31300
32044
32535
MIRROR M0 PLANE
MIRROR M1 PLANE
(MASK 2A) (MIS-STEERED BEAM, SEE SHEET 7)
WHITE BEAM STOP, PINK BEAM MASK
END OF A-HUTCH
39400
39600
39700
M2+GRATINGS
42283
PINK BEAM STOP
43700
MIRROR M3R MERIDIONAL CYLINDER, HORIZONTAL FOCUSING, RETRACTABLE
MONO BEAM ARPES
MONO BEAM RXSX
52910
53112
53657
53860
SHUTTERS C (MONO) 2x
SHUTTERS D (MONO) 2x
64300
MIRROR M3A ELLIPTICAL CYLINDER HORIZONTAL FOCUSING
65100
MIRROR M4A ELLIPTICAL CYLINDER DOWNWARD FOCUSING
MIRROR M4R ELLIPTICAL CYLINDER HORIZONTAL FOCUSING (64695)
(66300)
ARPES END STATION
RSXS END STATION 69693
NOTES:
1) THE SHIELDING DIMENSIONS IN THIS DRAWING REFLECT MINIMUM/MAXIMUM REQUIREMENTS. ALL COMPONENTS MUST MEET OR EXCEED THESE REQUIREMENTS.
2) Due to the multiple projection angles of the individual beamline branches, this drawing does not represent the exact location of the optics. Refer to the survey and alignment sheet for the exact mirror, slit and end chamber locations.
VERTICAL SCALE: 1:100
HORIZONTAL SCALE: 1:1
SYNCHROTRON VERTICAL VIEW SHEET 2
ARGONNE NATIONAL LABORATORY
ADVANCED PHOTON SOURCE
BEAMLINE ID, SECTOR 29
IEX BEAMLINE
RAYTRACE
4329-200000
REVISIONS


CENTER OF STRAIGHT SECTION
CL WHITE BEAM
(LEAD COLLIMATOR 4102040108-100000-01)
(SAFETY SHUTTER 4102040109-100000-01)
(WALL COLLIMATOR 4102040110-100000-00)
(EXIT COLLIMATOR 4102040111-200000-00)
MIRROR M0
MIRROR M1
PRIMARY BREMSSTRAHLUNG STOP, MATL: LEAD, t=300mm
END OF A-HUTCH
PRIMARY BREMSSTRAHLUNG
WHITE BEAM PATH
(LOW ENERGY PINK BEAM)
MIRROR M0,M1
SUPPLEMENTAL COLLIMATOR, SEE NOTE 3
SEE NOTE 1
END OF A-HUTCH
SECONDARY BREMSSTRAHLUNG
PINK BEAM PATH
SECONDARY BSR COLLIMATOR 3B, t=26mm (W)
SEE NOTE 2
SECONDARY BREMSSTRAHLUNG SHIELD
VACUUM TUBES with
LEAD WRAP t=12mm
SECONDARY BSR COLLIMATORS 2A, t=39mm (W)
SECONDARY BSR COLLIMATORS 1A, t=67mm (W)
MATERIAL DESCRIPTION
LEAD
TUNGSTEN
COPPER/GLID-COP
SST
ALUMINUM
NOTES:
1. LINES INDICATE SECONDARY BREMSSTRAHLUNG CREATED BY THE MIRROR. THE INFORMATION IS IN ACCORDANCE WITH APS DOCUMENT TB-21.
2. LINES INDICATE AREA OF SECONDARY BREMSSTRAHLUNG ALONG THE PINK BEAM PATH.
3. SUPPLEMENTAL COLLIMATOR FOR SECONDARY BREMSSTRAHLUNG. FOR EXTERNAL DIMENSIONS SEE ASSEMBLY DRAWING, SHEET 5.
4. THE SHIELDING DIMENSIONS IN THIS DRAWING REFLECT MINIMUM/MAXIMUM REQUIREMENTS. ALL COMPONENTS MUST MEET OR EXCEED THESE REQUIREMENTS.
VERTICAL SCALE: 1:100
HORIZONTAL SCALE: 1:1
X:Y SCALE:
BREMSSTRAHLUNG
HORIZONTAL VIEW
SHEET 3
REVISIONS
PARTS LIST / BILL OF MATERIALS
ARGONNE NATIONAL LABORATORY
ADVANCED PHOTON SOURCE
C. BENSON
08/13/2012
EXPERIMENTAL FACILITIES
BEAMLINE, ID, SECTOR 29
IEX BEAMLINE
RAYTRACE
E OHRH5 4329-200000 00
N/A
DO NOT SCALE DRAWING
SHEET 3

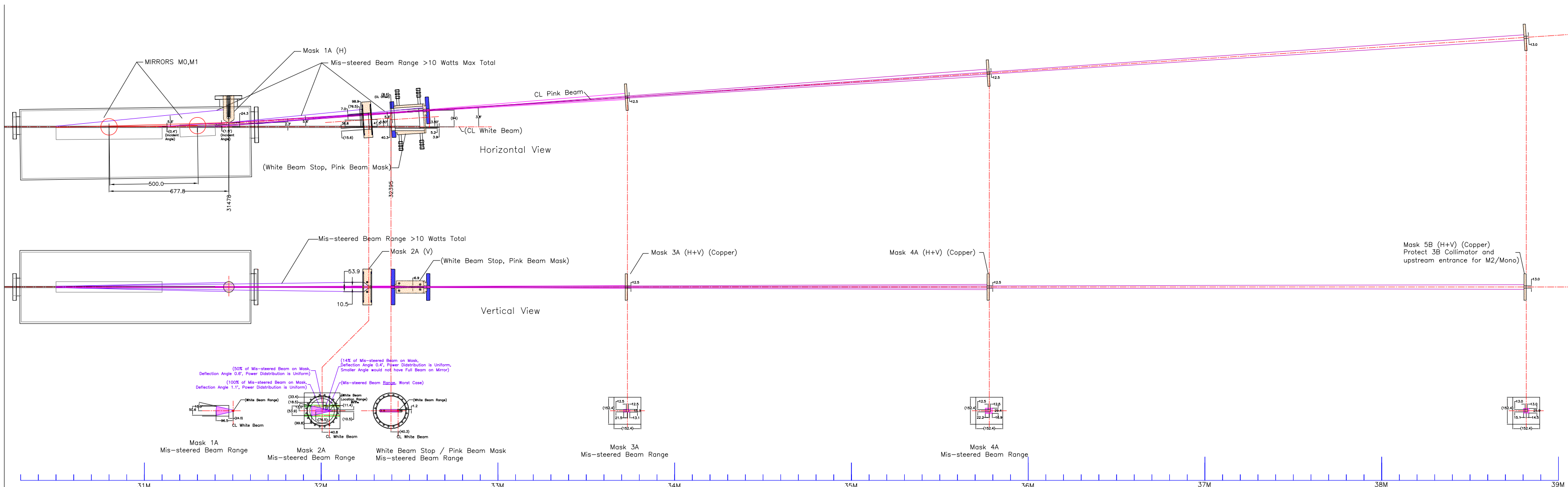

CENTER OF STRAIGHT SECTION
CL WHITE BEAM
(SAFETY SHUTTER 4102040109-100000-01)
(WALL COLLIMATOR 4102040110-100000-00)
(EXIT COLLIMATOR 4102040111-200000-00)
(22893)
(23347)
(24390)
(25924)
30800
31300
MIRROR M0
MIRROR M1
32917
33217
PRIMARY BREMSSTRAHLUNG STOP, MATL: LEAD, t=300mm
END OF A-HUTCH
PRIMARY BREMSSTRAHLUNG WHITE BEAM PATH
MIRROR M0,M1
SUPPLEMENTAL COLLIMATOR, SEE NOTE 3
31994
33812
35830
33855
SECONDARY BSR COLLIMATOR 1A, t=67mm (W)
SECONDARY BSR COLLIMATOR 2A, t=39mm (W)
SECONDARY BSR COLLIMATOR 3B, t=26mm (W,StStl)
END OF A-HUTCH
SECONDARY BREMSSTRAHLUNG PINK BEAM PATH
CL LOW ENERGY PINK BEAM
SEE NOTE 2
SECONDARY BREMSSTRAHLUNG SHIELD VACUUM TUBES with LEAD WRAPP t=12mm
SEE NOTE 1
SECONDARY BREMSSTRAHLUNG ALONG THE PINK BEAM PATH IS SHIELDED BY THE 1x1m x 2" THICK BACK WALL PANEL
MATERIAL DESCRIPTION
LEAD
TUNGSTEN
COPPER/GLID-COP
SST
ALUMINUM
NOTES:
1. LINES INDICATE SECONDARY BREMSSTRAHLUNG CREATED BY THE MIRROR. THE INFORMATION IS IN ACCORDANCE WITH APS DOCUMENT TB-21.
2. LINES INDICATE AREA OF SECONDARY BREMSSTRAHLUNG ALONG THE PINK BEAM PATH.
3. SUPPLEMENTAL COLLIMATOR FOR SECONDARY BREMSSTRAHLUNG. FOR EXTERNAL DIMENSIONS SEE ASSEMBLY DRAWING, SHEET 5.
4. THE SHIELDING DIMENSIONS IN THIS DRAWING REFLECT MINIMUM/MAXIMUM REQUIREMENTS. ALL COMPONENTS MUST MEET OR EXCEED THESE REQUIREMENTS.
VERTICAL SCALE: 1:100
HORIZONTAL SCALE: 1:1
X:Y SCALE: 100 / 1
BREMSSTRAHLUNG VERTICAL VIEW SHEET 4
PARTS LIST / BILL OF MATERIALS
DESIGNED BY: C. BENSON
DATE 08/13/2012
RESPONSIBLE ENGINEER: C. BENSON
MATERIAL: N/A
ARGONNE NATIONAL LABORATORY
ADVANCED PHOTON SOURCE
EXPERIMENTAL FACILITIES
BEAMLINE, ID, SECTOR 29
IEX BEAMLINE
RAYTRACE
SIZE E
FSCM No 0HRH5
DRAWING NUMBER 4329-200000
REV. 00
SCALE: See Note
DO NOT SCALE DRAWING
SHEET 4



FOE SIDE WALL t=19mm
FOE BACK WALL t=50mm
GUILLOTINE PANNEL t=50mm
BACK WALL PANNEL t=50mm
CENTER OF MO
(SUPPLEMENTAL COLLIMATOR)
(SECONDARY BREMSSTRAHLUNG)
(PRIMARY BREMSSTR STOP)
CL WHITE BEAM
3.8°
FOR SECONDARY BREMSSTRAHLUNG ALONG THE PINK BEAM PATH SEE SHEET 3 AND 4
(30800)
24M 25M 26M 27M 28M 29M 30M 31M 32M 33M 34M 35M 36M 37M
DISTANCE FROM CENTER OF STRAIGHT SECTION
31892
31994
32046
32236
32289
32398
32612
APS FRONT END EXIT TABLE
THE ELEVATION VIEW PAST 30.8 m FOLLOWS THE PINK BEAM CENTERLINE
THE SHIELDING DIMENSIONS IN THIS DRAWING REFLECT MINIMUM/MAXIMUM REQUIREMENTS. ALL COMPONENTS MUST MEET OR EXCEED THESE REQUIREMENTS.
MATERIAL DESCRIPTION
LEAD
TUNGSTEN
COPPER/GLID-COP
SST
ALUMINUM
SUPPLEMENTAL COLLIMATOR
SECONDARY BREMSSTRAHLUNG
SHEET 5
REVISIONS
PARTS LIST / BILL OF MATERIALS
ARGONNE NATIONAL LABORATORY
ADVANCED PHOTON SOURCE
EXPERIMENTAL FACILITIES
BEAMLINE, ID, SECTOR 29
IEX BEAMLINE
RAYTRACE
C. BENSON
08/13/2012
N/A
E OHRH5 4329-200000 00



CENTER OF STRAIGHT SECTION
CL WHITE BEAM
FOR SR RAY TRACE INSIDE OF THE A-HUTCH SEE SHEET 1
MATERIAL DESCRIPTION
LEAD
TUNGSTEN
COPPER/GLID-COP
SST
ALUMINUM
(30800)
(31300)
(32535)
(MIRROR M0)
(MIRROR M1)
(WHITE BEAM STOP, PINK BEAM MASK)
LOW ENERGY PINK BEAM
END OF A-HUTCH
3.8°
39400
39600
39700
M2+GRATINGS
42231
PINK BEAM STOP
43700
MIRROR M3R MERIDIONAL CYLINDER, HORIZONTAL FOCUSING, RETRACTABLE
MONOCHROMATIC BEAM
MONOCHROMATIC BEAM
52910
53112
SHUTTERS C (MONO) 2x
53657
53860
SHUTTERS D (MONO) 2x
2.5°
RSXS BRANCH
ARPES BRANCH
64300
65100
MIRROR M3A ELLIPTICAL CYLINDER HORIZONTAL FOCUSING
MIRROR M4A ELLIPTICAL CYLINDER DOWNWARD FOCUSING
66300
ARPES END STATION
MIRROR M4R MERIDIONAL CYLINDER, DOWNWARD FOCUSING
64695
RSXS END STATION
69693
SYNCHROTRON
HORIZONTAL VIEW
MONOCHROMATIC BEAM
SHEET 6
ARGONNE NATIONAL LABORATORY
ADVANCED PHOTON SOURCE
IEX BEAMLINE
RAYTRACE
4329-20000



MATERIAL DESCRIPTION	
LEAD	
TUNGSTEN	
COPPER/GLID-COP	
SST	
ALUMINUM	

Note:
At shielding commissioning run mirrors through all possible angles.

IEX BEAMLINE
RAY TRACE
MIS-STEERED BEAM FROM
MIRRORS M0 M1
08/13/2012, C. BENSON
4329-200000-00, SHEET 7

Sector 29-ID
IEX RSS Component Reference Table
8/9/12

	RSS Tag SA Bar Code	Component Description	Reference Drawing/ICMS Content ID #	Position			Apertures (min)				Material [thickness] (min)	PSS [EPS] Water Flow Rates (GPM/Channel)		Notes
							Optical Aperturee		Shielding Aperture					
				x* (mm)	y* (mm)	z (m) (Along 0° axis)	H (mm)	V (mm)	H (mm)	V (mm)		Nom	Min	
FOE "A"														
Center Line at 0°														
0		Front end exit mask	4102040106-310000-00			25.6	4.5	4.5						
0		Front end exit collimator	4102040111-200000-00			25.9	12	10	118	94				
1		Slits 1A (H+V)	4105091501-100000			28.8					GlidCop/W	4.0	2.4	
2		Side Bounce Mirror M0/M1	SOW 432908-00001-00			(30.5,31.3)	520/120	40/45			Si	Vendor	Vendor	
3		Mask 1A (H), missteered beam	4105091012-101200			31.5	24.3	N/A			GlidCop	4.0	2.4	M0/M1 Port
4		Supplemental Collimator	4105090405-3000000			32			115	60	Pb [50 mm]	N/A		
Center Line at -3.8°H, 0°V - Centerline starts at 31.19482m from Source (This is not the CL Mirror location!)														
5		D1A (Wire)				32.1								
6		Mask 2A (V), missteered beam	4105091012-101300			32.3	N/A	10.52			GlidCop	4.0	2.4	
7		White Beam Stop/Pink Beam Mask	4105091012-101040			32.6	6.5	6.5			Copper	4.0	2.4	Standard Mask
8		Primary Bremstrahlung Stop	4105091012-101110			33.2	38	∞	146	125	Pb [300 mm]	N/A		Vertical Blocks
11		Masks 3A, 4A	4105091012-101400			33.7, 35.8	12.5	12.5			Copper	N/A		
12		Mask 5B	4105091012-101500			38.8	13	13			Copper	N/A		
13		Secondary Bremstrahlung Collimators 1A	4105090405-210220			33.8			14	14	Tungsten [67mm]	N/A		
14		Secondary Bremstrahlung Collimator 2A	4105090405-210210			35.8			13.51	13.51	Tungsten [39mm]	N/A		
15		Secondary Bremstrahlung Collimator 3B	4105090405-210200			38.8			13.51	13.51	Tungsten [26mm]	N/A		
9		D2A (W,Mesh)				34								
10		Diagon				34.5						Vendor	Vendor	
APS Floor ("B")														
Center Line -3.8°H, 0°V - Centerline same as above														
16		Mirror/Monochromator M2+HEG, MEG, LEG	SOW 432908-00004-00			39.5						Vendor	Vendor	
Center Line -3.8°H, +0.8°V - Centerline starts at 40.77455m from Source (This is not the CL Monochromator location!)														
17		D3B (YAG/Au Mesh)				41								
18		Slits 2B (H)				42.8								
19		Pink Beam Stop	4105091008-100700			42.2	⌀2.4**				Copper	4.0	2.4	**Aperture for Mono
20		Mirror M3R (H)	SOW 432908-00002-04			43.7					Si	N/A		
21		D4CD (YAG)				44.8						N/A		
ARPES Beamline ("C") - Centerline same as above														
22		Shutter C (Mono)	4105090913-101000			53	25	25			SS	N/A		
23		D5C (YAG)	41050901701-101500											
24		Slits 3C (V)				59.7					SS	N/A		
25		Gas-Cell												
26		Mirror M3A (H)	SOW 432908-00003-01			64.3						N/A		
Center Line -6.8°H, +0.8°V - Centerline starts at 64.3m from Source														
27		Mirror M4A (V)	SOW 432908-00003-01			65.1					Si	N/A		
Center Line -6.8°H, -2.2° V - Centerline starts at 65.1m from Source														
28		D6C (YAG/Au Mesh/Diode)										N/A		
29		ARPES Endstation				66.3						N/A		
RSXS Beamline ("D")														
Center Line -1.3°H, +0.8°V - Centerline starts at 43.7m from Source														
30		Shutter D (Mono)	4105090913-101000			53.8	25	25			SS	N/A		
31		D5D (YAG)	41050901701-101500											
32		Slits 3D (V)				59.7					SS	N/A		
33		Mirror M4R (V)	SOW 432908-00002-04			64.7						N/A		
Center Line -1.3°H, -1.7°V - Centerline starts at 64.7m from Source														
34		D6D (YAG/Au Mesh/Diode)										N/A		
35		RSXS Endstation				69.7						N/A		

* x/y positions are listed on the assembly drawings to avoid miscomunication

Sector 29-ID
IEX RSS Component Reference Table
8/9/12

RSS component
RSS component not in PSS or EPS water flow
Not part of RSS, for reference only

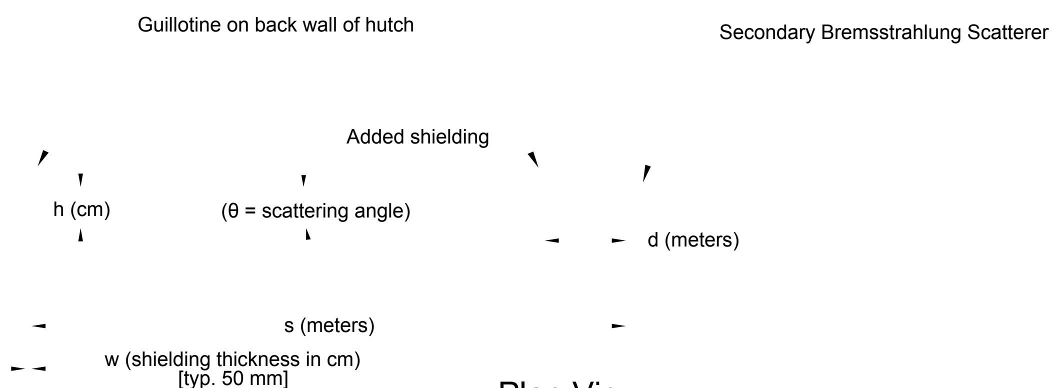
Shielding Specifications
29 ID-A White Beam Enclosure (FOE)

Source Type: Single EM-VPU		
Period	Length	Gap
12.5	4.8	10.5 mm

IEX Secondary Bremsstrahlung Calculations

(29ID-Mirror at 30.8m, back wall at 36m)
BSR between 0° and 1.5°/1.6° is shielded by the primary bremsstrahlung stop in the BL
BSR at 3.8° along the pink beam path, not shielded by the back wall, is shielded by the
secondary BSR collimator, t=10cm(Pb), 6.6cm(W)
BSR between 1.5° and 8°, with the exception of 3.8° beam path, is shielded by the
supplemental BSR collimator, t=3.3cm(Pb)

Input Data:			
distance from scatterer to back wall of hutch (s)	5.2	meters	
distance from bottom of guillotine to beam height	50	cm	5.5°
distance from beam center to inner edge of guillotine	50	cm	5.5°
back wall shielding thickness	5	cm	
guillotine shielding thickness	5	cm	



Plan View

Horizontal (Plan View)

angle	wall shielding w(θ)	TB-21 shielding (for 6.5m)	calc. shielding needed at back wall t(w) [cm]	calculated wall deficiency	Additional BSR shielding
0	10	15.4	16.3	6.3	
1	10	13.7	14.6	4.6	3.3
2	10	11.1	12.0	2.0	
3	10	9.6	10.5	0.5	10.0
4	10	8.2	9.1	0	
5	10	7.7	8.6	0	
6	5	7.4	8.3	3.3	
7	5	6.2	7.1	2.1	
8	5	4.8	5.7	0.7	

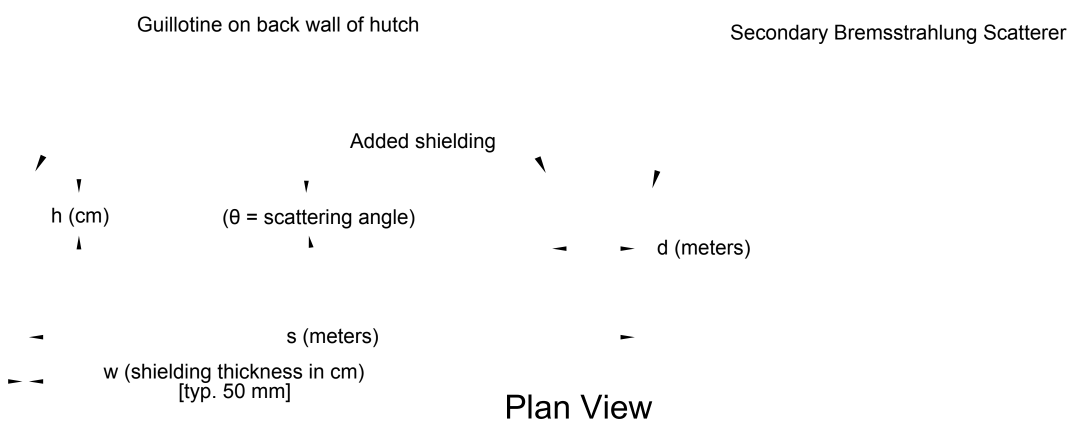
Vertical (Elevation View)

angle	wall shielding w(θ)	TB-21 shielding (for 6.5m)	calc. shielding needed at back wall t(w) [cm]	calculated wall deficiency	Additional shielding
0	10	15.4	16.3	6.3	
1	10	13.7	14.6	4.6	3.3
2	10	11.1	12.0	2.0	
3	10	9.6	10.5	0.5	10.0
4	10	8.2	9.1	0	
5	10	7.7	8.6	0	
6	5	7.4	8.3	3.3	
7	5	6.2	7.1	2.1	
8	5	4.8	5.7	0.7	

Secondary Bremsstrahlung Scatter Calculations
Out & Up

Input Data:		
distance from scatterer to back wall of hutch (s)	5.2	meters
distance from top of guillotine to beam height	50	cm
distance from beam center to outer edge of guillotine	82.5	cm
back wall shielding thickness	5	cm
guillotine shielding thickness	5	cm

5.5°
9.0°



Plan View

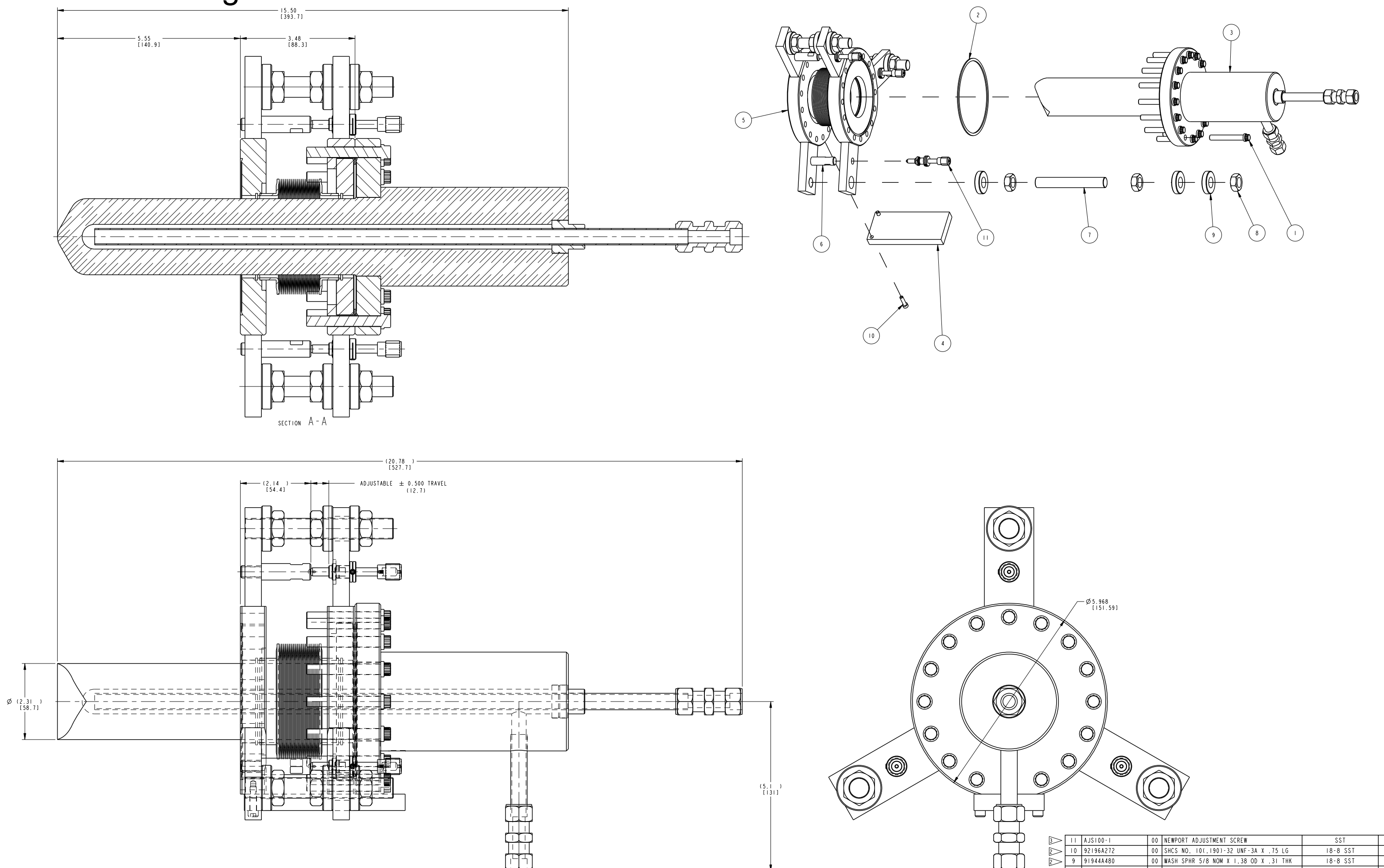
Horizontal (Plan View) (Outwards)

angle	wall shielding w(θ)	TB-21 shielding (for 6.5m)	calc. shielding needed at back wall t(w) [cm]	calculated wall deficiency
0	10	15.4	16.3	6.3
1	10	13.7	14.6	4.6
2	10	11.1	12.0	2.0
3	10	9.6	10.5	0.5
4	10	8.2	9.1	0
5	10	7.7	8.6	0
6	10	7.4	8.3	0
7	10	6.2	7.1	0
8	10	4.8	5.7	0

Vertical (Elevation View) (Upwards)

angle	wall shielding w(θ)	TB-21 shielding (for 6.5m)	calc. shielding needed at back wall t(w) [cm]	calculated wall deficiency
0	10	15.4	16.3	6.3
1	10	13.7	14.6	4.6
2	10	11.1	12.0	2.0
3	10	9.6	10.5	0.5
4	10	8.2	9.1	0
5	10	7.7	8.6	0
6	5	7.4	8.3	3.3
7	5	6.2	7.1	2.1
8	5	4.8	5.7	0.7

IEX Mis-steering Mask1A



NOTE:

1) THIS PART IS INTENDED FOR ULTRA HIGH VACUUM (UHV) SERVICE. THE USE OF SILICONE, SULFUR, PHOSPHOROUS, OR HALOGEN-BASED CUTTING FLUIDS AND ABRASIVES IS PROHIBITED. USE TRIMSOL OR APPROVED EQUIVALENT LUBRICANT. FOR COMPLETE SPECIFICATIONS ON MACHINING, VACUUM REQUIREMENTS, TESTING, AND DELIVERY PREPARATION, SEE ANL DOCUMENT NO. 410201-00095.

2) LEAK CHECK: NO DETECTABLE LEAKS WHEN TESTING AT 2×10^{-9} STD CC/SEC OF HELIUM

3) PROTECT KNIFE EDGES FROM DENTS, NICKS, AND SCRATCHES.

1 SOURCE OR EQUIVALENT
MDC VACUUM PRODUCTS, INC.
23842 CABOT BOULEVARD
HAYWARD, CA. 94545-1651
(510) 265-3500
www.mdc-vacuum.com

2 SOURCE OR EQUIVALENT
McMASTER CARR
P.O. BOX 4355
CHICAGO, IL 60680-4355
(630) 833-0300
www.mcmaster.com

3 SOURCE OR EQUIVALENT
NEWPORT CORPORATION
1791 DEERE AVE.
IRVINE, CA 92606
(800) 222-6440
www.newport.com

Source	ITEM	DRAWING / PART NUMBER	REV	NOMENCLATURE OR DESCRIPTION	MATERIAL / SPEC.	QTY
3	11	AJS100-1	00	NEWPORT ADJUSTMENT SCREW	SST	3
2	10	92196A272	00	SHCS NO. 10(.190)-32 UNF-3A X .75 LG	18-8 SST	2
2	9	91944A480	00	WASH SPHR 5/8 NOM X 1.38 OD X .31 THK	18-8 SST	9
2	8	91847A545	00	NUT HEX JAM 5/8-18 UNF-2B	18-8 SST	9
	7	4105091012-101216	00	STUD, THREADED 5/8-18 X 4.50 LONG S/S	18-8 SST	3
	6	4105091012-101215	00	STANDOFF, 1/2" OD W/ 3/8-16 STUD	18-8 SST	3
	5	4105091012-101208	00	WELDMENT, BELLOWS	SEE B.O.M. TABLE	1
	4	4105091012-101207	00	PLATE, STABILIZER	ALUM 6061-T6	1
	3	4105091012-101201	00	WELDMENT, MASK	SEE B.O.M. TABLE	1
1	2	191013	00	GASKET (6" FLANGE)	COPPER	1
1	1	190064	00	12-PT SCREW 5/16-24 X 2.25 LG	SP 304 SST	16

PARTS LIST / BILL OF MATERIALS

UNLESS OTHERWISE SPECIFIED ALL DIMENSIONS ARE IN INCHES
TOLERANCES
DECIMALS: .X ± .1, .XX ± .01, .XXX ± .005
ANGULAR: ± 0.5°
SURFACE ROUGHNESS 125
REMOVE ALL BURRS AND BREAK SHARP EDGES .03 MAX. SURFACE TEXTURE IN ACCORDANCE WITH LATEST ASME B46.1-2002 DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH LATEST ASME Y14.5M-1994

MODEL NAME: 4105091012-101200
ELECTRONIC FILE NAME: A4760900

DRAWN BY: N. POINDEXTER — DATE: 11-Oct-11
CHECKED BY:
DESIGNED BY: N. POINDEXTER — DATE: 11-Oct-11
RESPONSIBLE ENGINEER: C. BENSON
GROUP LEADER: P. DEN HARTOG
APPROVED BY:
RELEASE LEVEL: RELEASED — MODEL VER: 1 — DRWG VER: 1
MATERIAL: SEE B.O.M. TABLE

THIS DRAWING IS THE PROPERTY OF
Argonne NATIONAL LABORATORY — ADVANCED PHOTON SOURCE

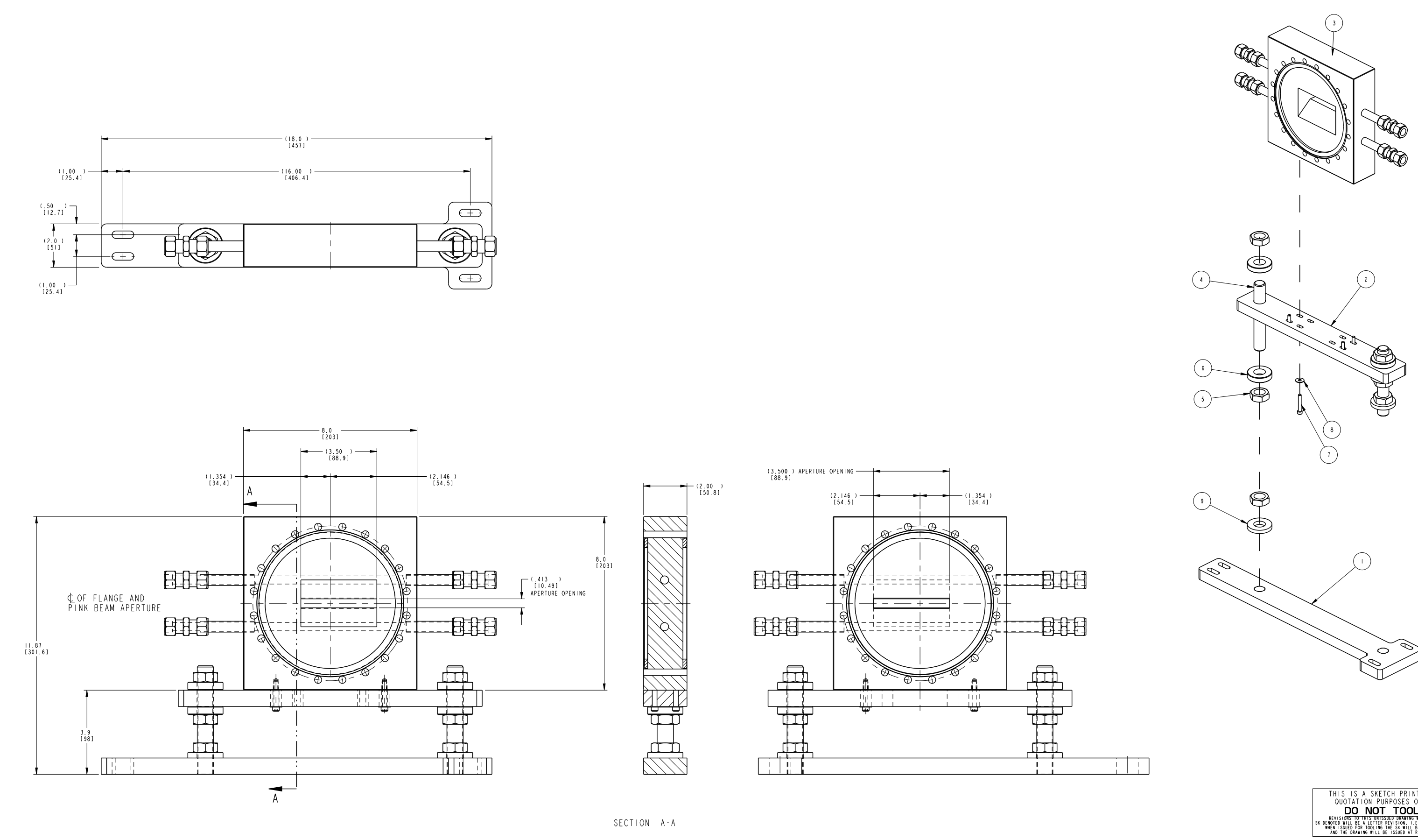
WBS DESCRIPTOR:
EXPERIMENTAL FACILITIES TECHNICAL COMPONENTS
XOR/SRI-CAT BEAMLINES
STANDARD COMPONENTS / MASKS
MASK, MISSTEERED BEAM

TITLE: MASK ASSEMBLY

SIZE: E — DRAWING NUMBER: 4105091012-101200 — REV: 00
SCALE: 1:1 — FSCM No: OHRH5 — DO NOT SCALE DRAWING — SHEET 1 OF 1

IEX Mis-steering Mask2A

REVISIONS					
ZONE	REV	DESCRIPTION	BY	APPROVED	DATE
	01	REFER TO DCN NO. 120118-01	NP		



THIS IS A SKETCH PRINT FOR QUOTATION PURPOSES ONLY

DO NOT TOOL

REVISIONS TO THIS UNISSUED DRAWING WITH THE SK DENOTED WILL BE A LETTER REVISION, I.E. A, B, ETC. WHEN ISSUED FOR TOOLING THE SK WILL BE REMOVED AND THE DRAWING WILL BE ISSUED AT REV '00'

NOTES:

1) THIS PART IS INTENDED FOR ULTRA HIGH VACUUM (UHV) SERVICE. THE USE OF SILICONE, SULFUR, PHOSPHOROUS, OR HALOGEN-BASED CUTTING FLUIDS AND ABRASIVES IS PROHIBITED. USE TRIMSOL OR APPROVED EQUIVALENT LUBRICANT. FOR COMPLETE SPECIFICATIONS ON MACHINING, VACUUM REQUIREMENTS, TESTING, AND DELIVERY PREPARATION, SEE ANL DOCUMENT NO. 410201-00095.

2) PROTECT KNIFE EDGES FROM DENTS, NICKS, AND SCRATCHES.

3) LEAK CHECK: NO DETECTABLE LEAKS WHEN TESTING AT 2 x 10^{-9} STD CC/SEC OF HELIUM.

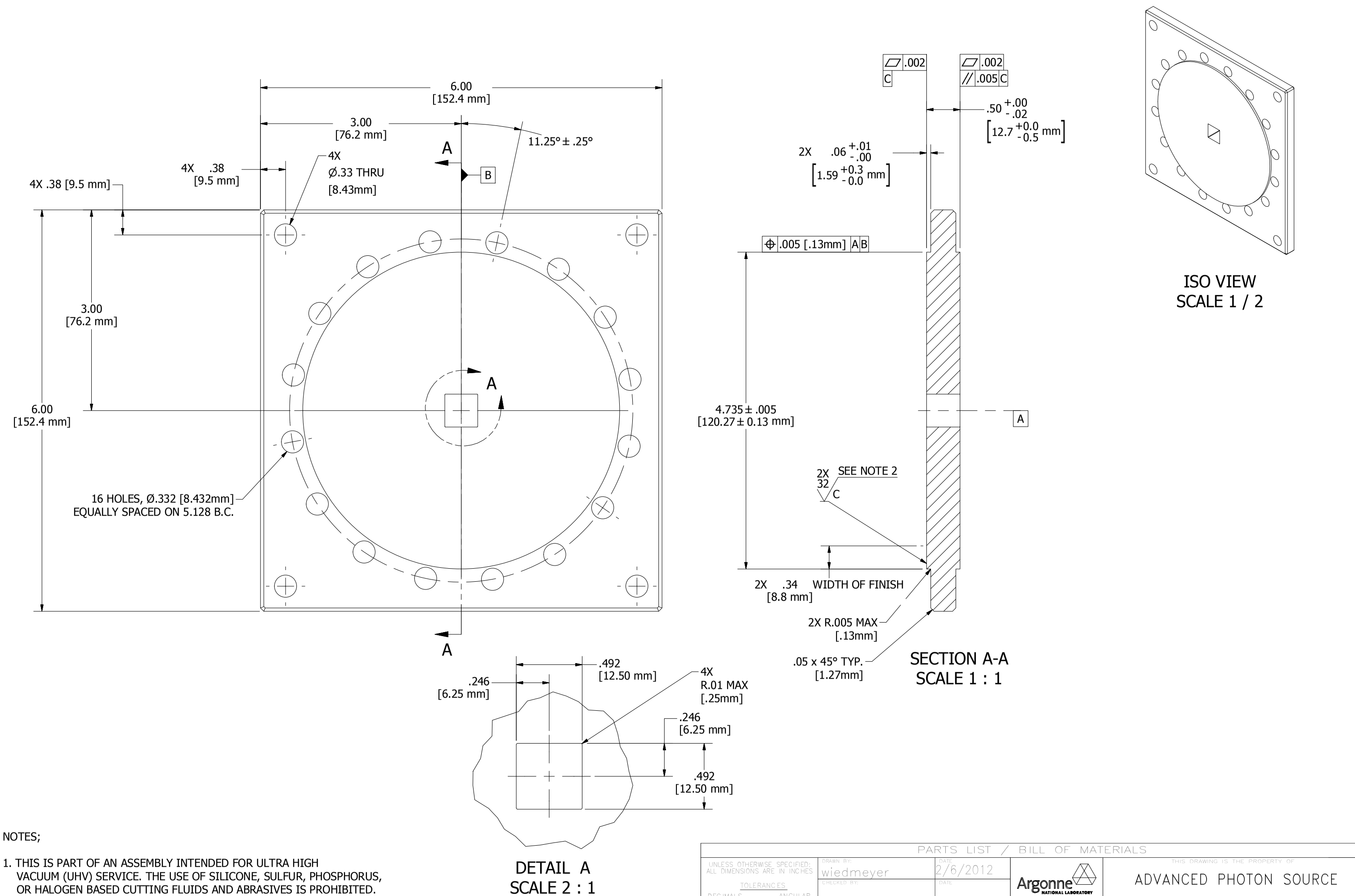
▷1 SOURCE OR EQUIVALENT
McMASTER-CARR
P.O. BOX 4355
CHICAGO, IL 60680-4355
630-883-0300

	ITEM	DRAWING / PART NUMBER	REV	NOMENCLATURE OR DESCRIPTION	MATERIAL / SPEC.	QTY
▷1	9	98125A036	12	WASH FLT 3/4 NOM X 1.63 OD X .25 THK	18-8 SST	2
▷1	8	92217A445	11	WASHER, FLT #10 SCREW .203 ID X .563 OD	18-8 SST	4
▷1	7	92196A276	11	SHCS NO. 10(.190)-32 UNF-3A X 1.25 LG	18-8 SST	4
▷1	6	91944A490	12	WASH SPHR 3/4 NOM X 1.63 OD X .38 THK	18-8 SST	4
▷1	5	91847A555	13	NUT HEX JAM 3/4-16 UNF-2B	18-8 SST	6
	4	4105091012-101306	01	STUD, THREADED 3/4-16 UNF S/S X 5.0 LG.	18-8 SST	2
	3	4105091012-101301	02	ASSEMBLY, MASK	SEE B.O.M. TABLE	1
	2	4105091012-101219	00	PLATE, MTG. 3/4 X 2.00 X 14.00	6061-T6 ALUM	1
	1	4105091012-101218	00	PLATE, SUPT 3/4" THK. X 2.00 W. X 18.00 L.	6061-T6 ALUM	1

PARTS LIST / BILL OF MATERIALS

UNLESS OTHERWISE SPECIFIED ALL DIMENSIONS ARE IN INCHES TOLERANCES DECIMALS .X ± .1 .XX ± .01 .XXX ± .005 ANGULAR ± 0.5° SURFACE ROUGHNESS 125	DRAWN BY: N. POINDEXTER	DATE 14-May-12	THIS DRAWING IS THE PROPERTY OF Argonne NATIONAL LABORATORY ADVANCED PHOTON SOURCE
	CHECKED BY:	DATE	
REMOVE ALL BURRS AND BREAK SHARP EDGES .03 MAX. SURFACE TEXTURE IN ACCORDANCE WITH LATEST ASME B46.1-2002 DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH LATEST ASME Y14.5M-1994	DESIGNED BY: N. POINDEXTER	DATE 14-May-12	WBS DESCRIPTOR: EXPERIMENTAL FACILITIES TECHNICAL COMPONENTS XOR/SRI-CAT BEAMLINE STANDARD COMPONENTS MASK / MISSTEERED BEAM
	RESPONSIBLE ENGINEER: C. BENSON	DATE	
	GROUP LEADER: P. DEN HARTOG	DATE	
	APPROVED BY:	DATE	TITLE: ASSEMBLY, MASK
MODEL NAME: 4105091012-101300	RELEASE LEVEL: WIP	MODEL VER: 1 DRWG VER: 0	SIZE E DRAWING NUMBER: 4105091012-101300 SHT. DES. REV. 03
ELECTRONIC FILE NAME: A4760502	MATERIAL: SEE B.O.M. TABLE		SCALE: 5:8 FSCM No: 0HRH5 DO NOT SCALE DRAWING SHEET 1 OF 1

IEX Mis-steering Mask3A and Mask4A



NOTES;

1. THIS IS PART OF AN ASSEMBLY INTENDED FOR ULTRA HIGH VACUUM (UHV) SERVICE. THE USE OF SILICONE, SULFUR, PHOSPHORUS, OR HALOGEN BASED CUTTING FLUIDS AND ABRASIVES IS PROHIBITED. USE TRIMSOL OR APPROVED EQUIVALENT LUBRICANT. FOR COMPLETE SPECIFICATIONS ON MACHINING, VACUUM REQUIREMENTS, TESTING AND DELIVERY PREPARATION, SEE ANL DOCUMENT 410201-00095.

2. PROTECT FINISH SURFACES FROM DENTS, NICKS AND TRANSVERSE SCRATCHES.

3. CLEAN FOR 10^{-9} TORR SERVICE.

4. ESTIMATED WEIGHT = 10.3 LBS

PARTS LIST / BILL OF MATERIALS

UNLESS OTHERWISE SPECIFIED: ALL DIMENSIONS ARE IN INCHES

TOLERANCES: DECIMALS .X ± 0.1, .XX ± 0.03, .XXX ± 0.005; ANGULAR ± .5°

SURFACE ROUGHNESS: 125

REMOVE ALL BURRS AND BREAK SHARP EDGES .03 MAX. SURFACE TEXTURE IN ACCORDANCE WITH LATEST ASME B46.1-2002. DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH LATEST ASME Y14.5M-1994

DRAWN BY: wiedmeyer — DATE: 2/6/2012

DESIGNED BY: wiedmeyer — DATE: 2/6/2012

RESPONSIBLE ENGINEER: C. BENSON

GROUP LEADER: PAT DEN HARTOG

RELEASE STATUS: RELEASED

MATERIAL: COPPER, C10100 OFE, PER ASTM B152

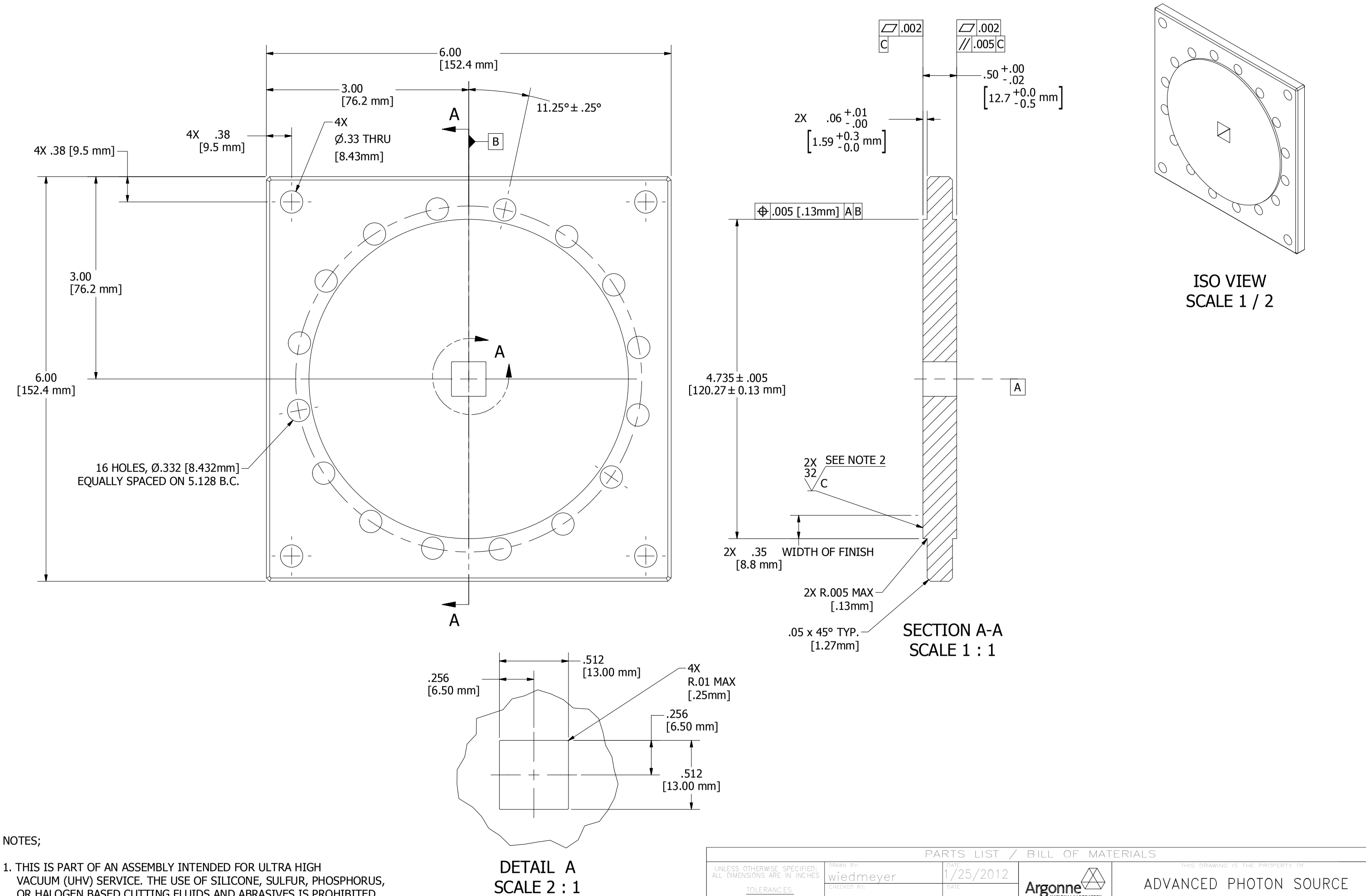
THIS DRAWING IS THE PROPERTY OF Argonne NATIONAL LABORATORY — ADVANCED PHOTON SOURCE

EXPERIMENTAL FACILITIES TECHNICAL COMPONENTS
XOR/SRI-CAT BEAMLINE
STANDARD COMPONENTS
MASK / MISSTEERED BEAM, 12.5mm APERTURE

C | 0HRH5 | 4105091012-101400 | 00

SCALE: FULL | DO NOT SCALE DRAWING | SHEET 1 OF 1

IEX Mis-steering Mask5B



NOTES;

1. THIS IS PART OF AN ASSEMBLY INTENDED FOR ULTRA HIGH VACUUM (UHV) SERVICE. THE USE OF SILICONE, SULFUR, PHOSPHORUS, OR HALOGEN BASED CUTTING FLUIDS AND ABRASIVES IS PROHIBITED. USE TRIMSOL OR APPROVED EQUIVALENT LUBRICANT. FOR COMPLETE SPECIFICATIONS ON MACHINING, VACUUM REQUIREMENTS, TESTING AND DELIVERY PREPARATION, SEE ANL DOCUMENT 410201-00095.
2. PROTECT FINISH SURFACES FROM DENTS, NICKS AND TRANSVERSE SCRATCHES.
3. CLEAN FOR 10^{-9} TORR SERVICE.
4. ESTIMATED WEIGHT = 10.3 LBS

PARTS LIST / BILL OF MATERIALS

UNLESS OTHERWISE SPECIFIED: ALL DIMENSIONS ARE IN INCHES
TOLERANCES
DECIMALS: .X ± 0.1; .XX ± 0.03; .XXX ± 0.005
ANGULAR: ± .5°
SURFACE ROUGHNESS: 125

REMOVE ALL BURRS AND BREAK SHARP EDGES .03 MAX. SURFACE TEXTURE IN ACCORDANCE WITH LATEST ASME B46.1-2002. DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH LATEST ASME Y14.5M-1994

DRAWN BY	wiedmeyer	1/25/2012
DESIGNED BY	wiedmeyer	1/25/2012
RESPONSIBLE ENGINEER	C. BENSON	
GROUP LEADER	PAT DEN HARTOG	
RELEASE LEVEL	RELEASED	
MATERIAL	COPPER, C10100 OFE, PER ASTM B152	

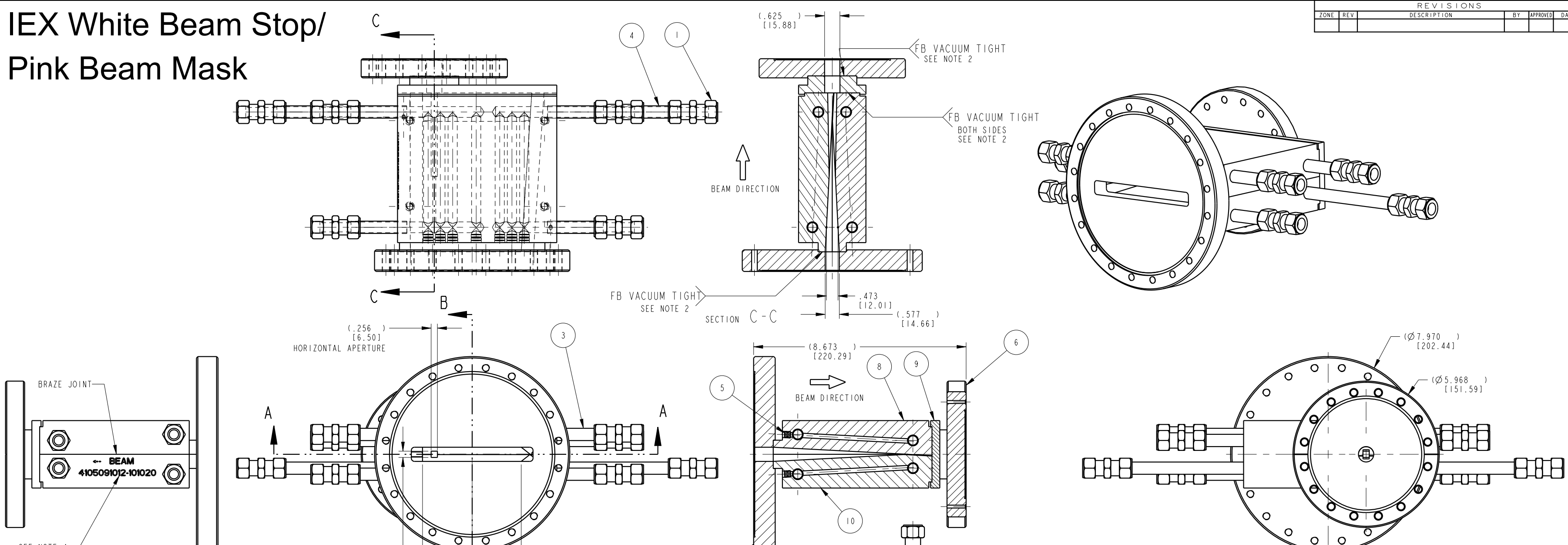
THIS DRAWING IS THE PROPERTY OF Argonne NATIONAL LABORATORY — ADVANCED PHOTON SOURCE

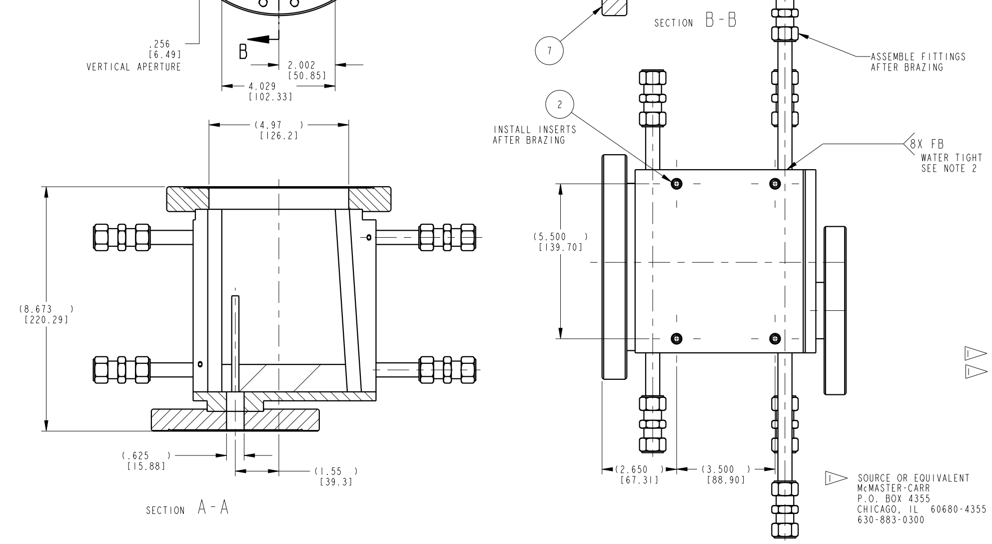
EXPERIMENTAL FACILITIES TECHNICAL COMPONENTS
XOR/SRI-CAT BEAMLINE
STANDARD COMPONENTS
MASK / MISSTEERED BEAM, 13mm APERTURE

C | 0HRH5 | 4105091012-101500 | 00

SCALE: FULL | DO NOT SCALE DRAWING | SHEET 1 OF 1

IEX White Beam Stop/ Pink Beam Mask





SOURCE OR EQUIVALENT
McMASTER-CARR
P.O. BOX 4355
CHICAGO, IL 60680-4355
630-883-0300

NOTES:

1. DIMENSIONS IN BRACKETS ARE MILLIMETERS AND FOR REFERENCE ONLY.
2. FOR COMPLETE SPECIFICATIONS ON BRAZING, SEE ANL DOCUMENT NO. 410201-00122.
3. THIS ASSEMBLY IS INTENDED FOR ULTRA HIGH VACUUM (UHV) SERVICE. THE USE OF SILICONE, SULPHUR, PHOSPHORUS OR HALOGEN BASED CUTTING FLUIDS AND ABRASIVES IS PROHIBITED. USE TRIMSOL OR APPROVED EQUIVALENT LUBRICANT. FOR COMPLETE SPECIFICATIONS ON MACHINING, VACUUM REQUIREMENTS, TESTING AND DELIVERY PREPARATION, SEE ANL DOCUMENT NO. 410201-00095.
4. LASER ETCH OR MACHINE ENGRAVE ASSEMBLY NUMBER AND BEAM DIRECTION (WITH ARROW POINTING TOWARDS SMALLER APERTURE) ON BOTH SIDES OF PART AS SHOWN USING MIN. 1/4" HIGH CHARACTERS:

PARTS LIST / BILL OF MATERIALS

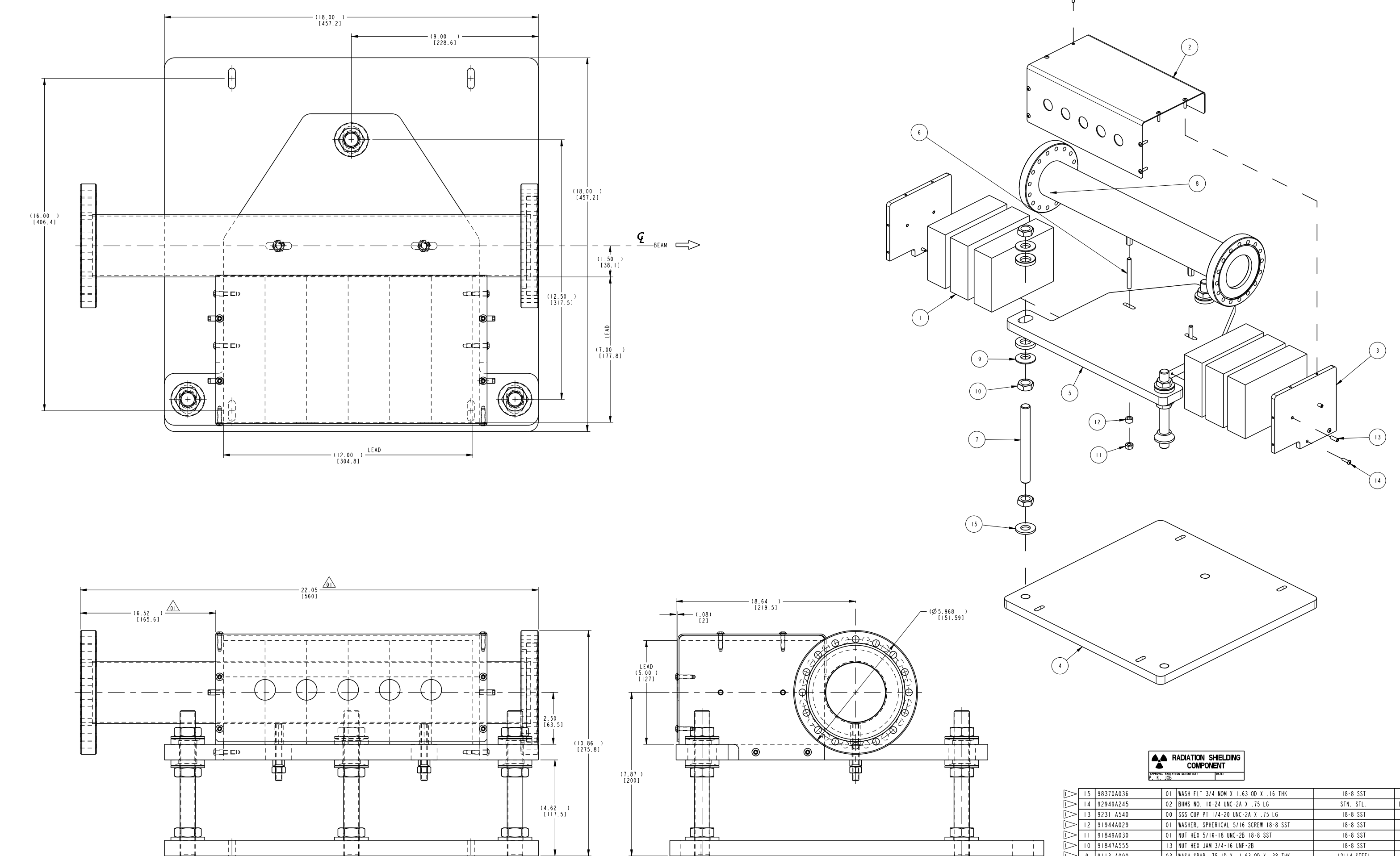
ITEM	DRAWING / PART NUMBER	REV	NOMENCLATURE OR DESCRIPTION	MATERIAL / SPEC.	QTY
10	4105091012-101006	00	LOWER MASK HALF W/ DOWEL	PARTS LIST	1
9	4105091012-101005	00	END PLATE	OFHC COPPER	1
8	4105091012-101003	00	UPPER MASK HALF	OFHC COPPER	1
7	4105091012-101002	00	FLANGE, 8"	PARTS LIST	1
6	4105091012-101001	00	FLANGE, 6"	PARTS LIST	1
5	4102030101-101103	01	PLUG	OFHC COPPER	14
4	4105091012-101007	00	COOLANT TUBE	SST	2
3	N1120303-201103	00	COOLANT TUBE	SST	6
2	CL-1420-TSKS	01	KEY INSERT 1/4-20 UNC-2B (INT THD)	303 SST	4
1	8-8-HBZ-SS	11	UNION STR. CPI Ø1/2 x Ø1/2 TUBE TO TUBE	316 SST	8

UNLESS OTHERWISE SPECIFIED ALL DIMENSIONS ARE IN INCHES. TOLERANCES DECIMALS .X ±.1 .XX ±.03 .XXX ±.005 ANGULAR ±0.5° SURFACE ROUGHNESS 125	DRAWN BY: P GUNKELMAN	DATE 31-Jan-11	Argonne NATIONAL LABORATORY ADVANCED PHOTON SOURCE
REMOVE ALL BURRS AND BREAK SHARP EDGES .03 MAX. SURFACE TEXTURE IN ACCORDANCE WITH LATEST ASME B46.1-2002 DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH LATEST ASME Y14.5M-1994	DESIGNED BY: P GUNKELMAN	DATE 31-Jan-11	WBS DESCRIPTOR: EXPERIMENTAL FACILITIES TECHINCAL COMPONENTS XOR/SRI-CAT BEAMLINES STANDARD COMPONENTS/ PHOTON MASKS WHITE BEAM STOP/PINK BEAM MASK
	RESPONSIBLE ENGINEER: C BENSON		
	GROUP LEADER: P. DEN HARTOG		TITLE: BRAZE ASSEMBLY
MODEL NAME: 4105091012-101020	RELEASE LEVEL: RELEASED	MODEL VER 28 DRW VER 23	SIZE D DRAWING NUMBER: 4105091012-101020 REV. 00
ELECTRONIC FILE NAME: A4730700	MATERIAL: PARTS LIST		SCALE: 1:2 DO NOT SCALE DRAWING SHEET 1 OF 1

REVISIONS

ZONE	REV	DESCRIPTION	BY	APPROVED	DATE

IEX Primary Bremsstrahlung Stop



RADIATION SHIELDING COMPONENT

APPROVAL RADIATION SCIENTIST: P. K. JOB DATE:

ITEM	DRAWING / PART NUMBER	REV	NOMENCLATURE OR DESCRIPTION	MATERIAL / SPEC.	QTY
15	98370A036	01	WASH FLT 3/4 NOM X 1.63 OD X .16 THK	18-8 SST	3
14	92949A245	02	BHMS NO. 10-24 UNC-2A X .75 LG	STN. STL.	12
13	92311A540	00	SSS CUP PT 1/4-20 UNC-2A X .75 LG	18-8 SST	4
12	91944A029	01	WASHER, SPHERICAL 5/16 SCREW 18-8 SST	18-8 SST	2
11	91849A030	01	NUT HEX 5/16-18 UNC-2B 18-8 SST	18-8 SST	2
10	91847A555	13	NUT HEX JAM 3/4-16 UNF-2B	18-8 SST	9
9	91131A090	03	WASH SPHR .75 ID X. 1.63 OD X .38 THK	12L14 STEEL	6
8	4105090403-201100	01	TUBE WELDMENT	PARTS LIST	1
7	4105090403-200008	00	STUD, THREADED 3/4-16 UNF S/S X 7.00 LG.	18-8 SST	3
6	4105090403-200007	00	STUD, THREADED 5/16-18 UNF X 2-3/4 LG. SST	18-8 SST	2
5	4105090403-200006	00	PLATE, BASE 3/4" TH X 18.00 W X 15.00 L	AL 6061-T6	1
4	4105090403-200004	00	PLATE, SUPPORT 3/4" TH X 18.00 W X 15.00 L	AL 6061-T6	1
3	4105090403-200003	00	PLATE, SIDE COVER MOUNTING	ALUM ALLOY 6061-T6	2
2	4105090403-200002	00	COVER, LEAD RETAINER	0.063 ALUM 1100-H14 SHT.	1
1	4105090403-200001	00	BAR, LEAD 2.00 TH X 5.00 H X 7.00 LENGTH	LEAD GRD B, 99.9% LEAD	6

PARTS LIST / BILL OF MATERIALS

NOTES:

1) APPROXIMATE WEIGHT: 239.57 LBS.

2. THIS COMPONENT IS PART OF AN ASSEMBLY INTENDED FOR ULTRA HIGH VACUUM (UHV) SERVICE. THE USE OF SILICONE, SULPHUR, PHOSPHORUS OR HALOGEN BASED CUTTING FLUIDS AND ABRASIVES IS PROHIBITED. USE TRIMSOL OR APPROVED EQUIVALENT LUBRICANT. FOR COMPLETE SPECIFICATIONS ON MACHINING, VACUUM REQUIREMENTS, TESTING AND DELIVERY PREPARATION, SEE ANL DOCUMENT NO. 410201-00095.

3) PROTECT KNIFE EDGES FROM DENTS, NICKS, AND SCRATCHES.

SOURCE OR EQUIVALENT
McMASTER-CARR
P.O. BOX 4355
CHICAGO, IL 60680-4355
630-883-0300

UNLESS OTHERWISE SPECIFIED ALL DIMENSIONS ARE IN INCHES
TOLERANCES
DECIMALS .X ± .1 .XX ± .03 .XXX ± .005
ANGULAR ± 0.5°
SURFACE ROUGHNESS 125
REMOVE ALL BURRS AND BREAK SHARP EDGES .03 MAX. SURFACE TEXTURE IN ACCORDANCE WITH LATEST ASME B46.1-2002 DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH LATEST ASME Y14.5M-1994

DRAWN BY: P GUNKELMAN DATE: 10-Jan-12
CHECKED BY:
DESIGNED BY: P GUNKELMAN DATE: 10-Jan-12
RESPONSIBLE ENGINEER: C BENSON
GROUP LEADER: P. DEN HARTOG
APPROVED BY:

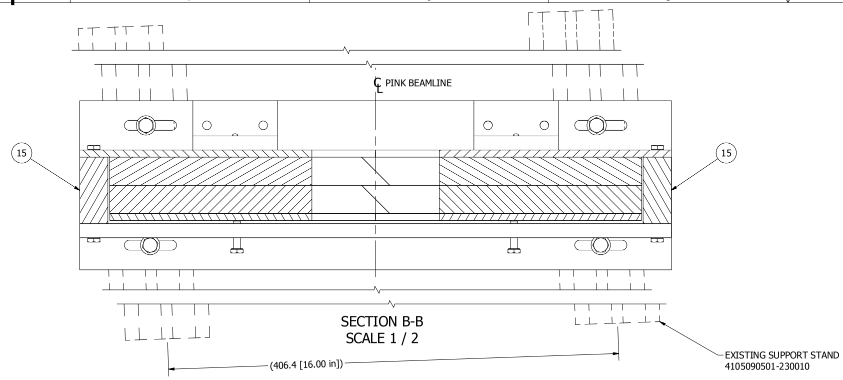
THIS DRAWING IS THE PROPERTY OF Argonne NATIONAL LABORATORY ADVANCED PHOTON SOURCE

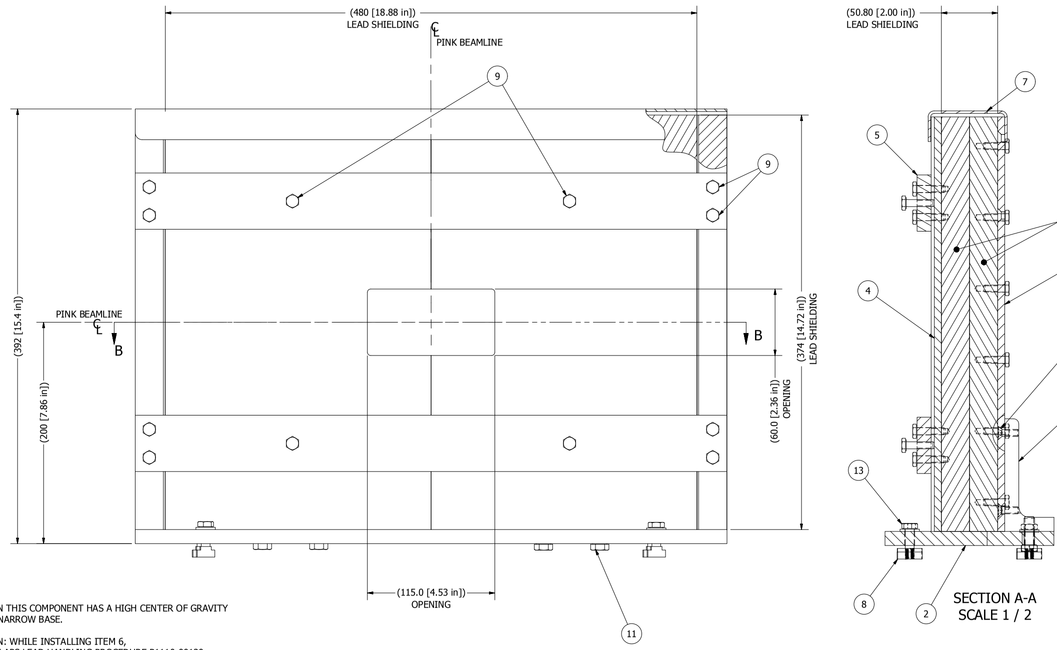
WBS DESCRIPTOR: EXPERIMENTAL FACILITIES TECHINCAL COMPONENTS BEAMLINES STANDARD COMPONENTS / BREMSSTRAHLUNG PRIMARY BREMSSTRAHLUNG STOP

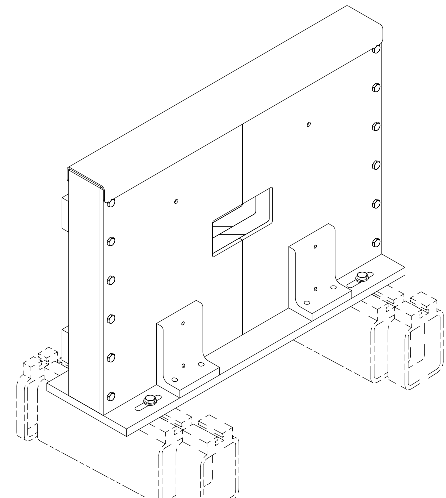
TITLE: ASSEMBLY, BREMSSTRAHLUNG STOP

MODEL NAME: 4105090403-201000
RELEASE LEVEL: WIP
MODEL VER: 1 DRWG VER: 0
SIZE: E
DRAWING NUMBER: 4105090403-201000
REV: 01
ELECTRONIC FILE NAME: A4785100
MATERIAL: PARTS LIST
SCALE: 3:4
DO NOT SCALE DRAWING
SHEET 1 OF 1

IEX Supplemental Collimator







EXPLODED ISOMETRIC VIEW
FROM BACK SIDE

ITEM	QTY	PART NUMBER	DESCRIPTION
15	2	4105090405-300308	CLAMP SUPPORT BAR
14	4		Countersunk Flat Head Screw, 1/4-20 UNC x .75 ZINC PLATED STL
13	4		Hex Cap Screw, 5/16-18 UNC x 1" ZINC PLATED STL
12	4		Washer, Flat 5/16 ZINC PLATED STL
11	4		Hex Cap Screw, 3/8-16 UNC x 1" ZINC PLATED STL
10	12		Hex Cap Screw. 1/4-20 UNC x .75" ZINC PLATED STL
9	12		Hex Cap Screw, 1/4-20 UNC x 1" ZINC PLATED STL
8	4	94750A580	TEE NUT, 5/16-18
7	1	4105090405-300307	COVER / TOP
6	4	4105090405-300306	LEAD
5	2	4105090405-300305	BAR / CROSS
4	2	4105090405-300304	PLATE / FRONT
3	2	4105090405-300303	SUPPORT / ANGLE
2	1	4105090405-300302	PLATE / BASE
1	2	4105090405-300301	PLATE, BACKING

PARTS LIST

NOTES;
1. CAUTION THIS COMPONENT HAS A HIGH CENTER OF GRAVITY AND A NARROW BASE.

2. CAUTION: WHILE INSTALLING ITEM 6, FOLLOW APS LEAD HANDLING PROCEDURE P1110-00120

3. BEFORE INSTALLING ITEM 6 OF THIS ASSEMBLY, BE SURE EXISTING SUPPORT STAND (REFERENCED ABOVE) IS SECURELY FASTENED TO FLOOR USING FLOOR ANCHORS.

SOURCE OR EQUIVALENT
McMASTER CARR
P.O. BOX 4355
CHICAGO, IL 6-680-4355
630-883-0300

PARTS LIST / BILL OF MATERIALS

wiedmeyer 3/28/2012
wiedmeyer 3/28/2012
PAT DEN HARTOG
WorkInProgress

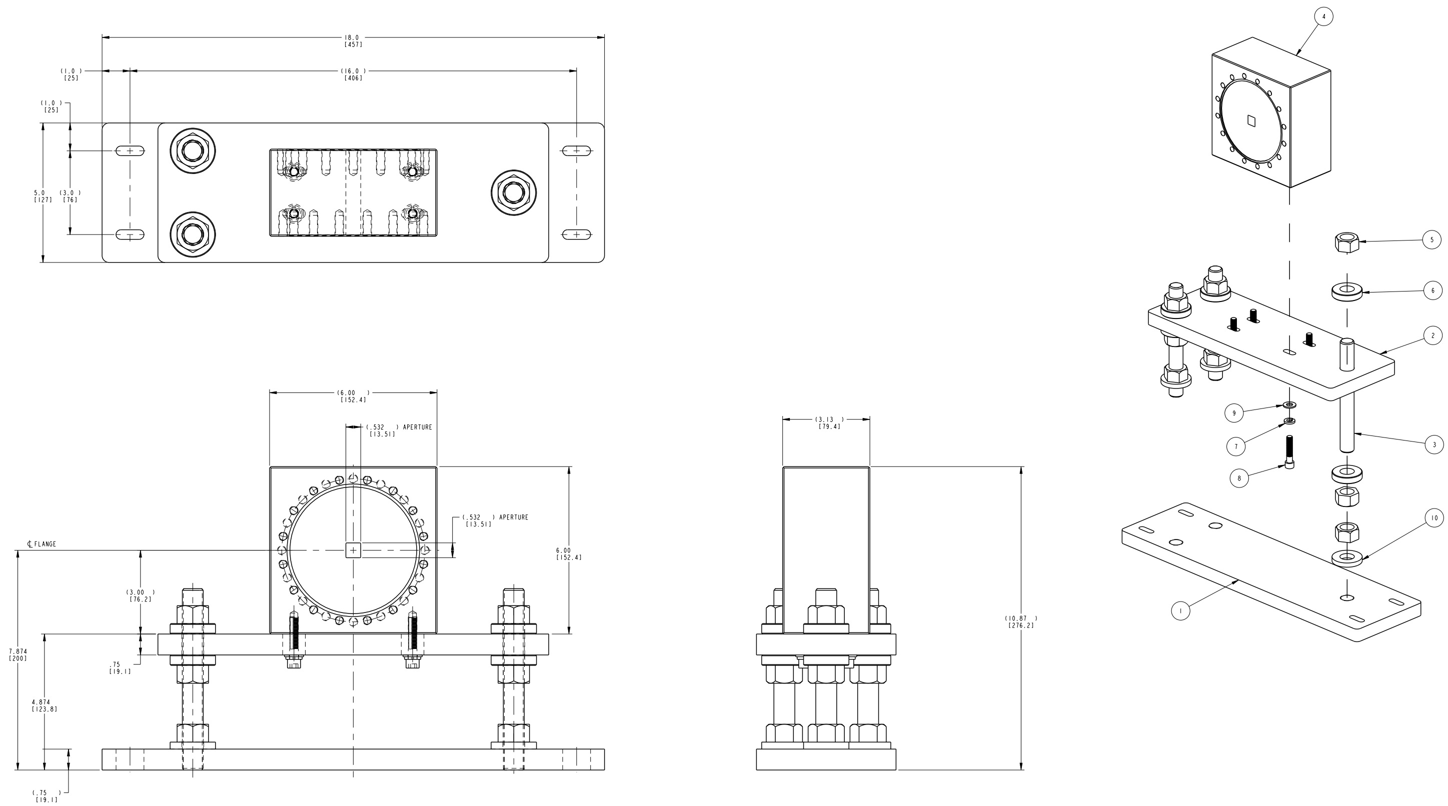
Argonne — ADVANCED PHOTON SOURCE

EXPERIMENTAL FACILITIES TECHNICAL COMPONENTS
XOR/SRI-CAT BEAMLINE
STANDARD COMPONENTS
SUPPLEMENTAL COLLIMATORS ASSEMBLY, SUPPLEMENTAL COLLIMATOR

D 0HRH5 4105090405-300300

DO NOT SCALE DRAWING

IEX Secondary Bremsstrahlung Collimator 1A



▷	10	98125A036	11	WASH FLT 3/4 NOM X 1.63 OD X .25 THK	18-8 SST	3
▷	9	98019A385	01	WASH FLT 5/16 x .69 OD x .05 THK	18-8 SST	4
▷	8	92196A344	02	SHCS 5/16-24 UNF-3A x 1.50 LG	SST 18-8	4
▷	7	92146A030	01	WASH LOCK 5/16 NOM x .58 OD x .09 THK	18-8 SST	4
▷	6	91944A490	11	WASH SPHR 3/4 NOM X 1.63 OD X .38 THK	18-8 SST	6
▷	5	91845A175	01	NUT HEX 3/4-16 UNF-2B	18-8 SST	9
	4	4105090405-210221	00	BODY, COLLIMATOR (3.00 THICK)	SEE NOTE #2	1
	3	4105090405-210207	01	STUD, THREADED 3/4-16 UNF X 6 1/2" LONG	18-8 SST	3
	2	4105090405-210206	01	PLATE, MOUNTING	PLATE ALUM 6061-T6	1
	1	4105090405-210205	01	PLATE, SUPT 3/4" THK. X 5.00 W. X 18.00 L.	ALUM 6061-T6	1
	ITEM	DRAWING / PART NUMBER	REV	NOMENCLATURE OR DESCRIPTION	MATERIAL / SPEC.	QTY

PARTS LIST / BILL OF MATERIALS

UNLESS OTHERWISE SPECIFIED ALL DIMENSIONS ARE IN INCHES
TOLERANCES
DECIMALS: .X ± .1, .XX ± .01, .XXX ± .005
ANGULAR: ± 0.5°
SURFACE ROUGHNESS 125

REMOVE ALL BURRS AND BREAK SHARP EDGES .03 MAX. SURFACE TEXTURE IN ACCORDANCE WITH LATEST ASME B46.1-2002 DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH LATEST ASME Y14.5M-1994

DRAWN BY: N. POINDEXTER	DATE: 20-Mar-12	THIS DRAWING IS THE PROPERTY OF Argonne National Laboratory	ADVANCED PHOTON SOURCE
CHECKED BY:	DATE:	WBS DESCRIPTOR:	EXPERIMENTAL FACILITIES TECHNICAL COMPONENTS XOR / SRI-CAT BEAMLINES STANDARD COMPONENTS / COLLIMATORS BREMSSTRAHLUNG COLLIMATOR
DESIGNED BY: N. POINDEXTER	DATE: 20-Mar-12		
RESPONSIBLE ENGINEER: C. BENSON	DATE:		
GROUP LEADER: P. DEN HARTOG	DATE:		
APPROVED BY:	DATE:	TITLE:	ASSEMBLY, 3.13 THICK COLLIMATOR
MODEL NAME: 4105090405-210220	RELEASE LEVEL: RELEASED	MODEL VER: 1 / DRWG VER: 1	SIZE: E — DRAWING NUMBER: 4105090405-210220 — REV. 00
ELECTRONIC FILE NAME: A4873800	MATERIAL: SEE B.O.M. TABLE	SCALE: 3:4 — FSCM No: OHRH5	DO NOT SCALE DRAWING — SHEET 1 OF 1

REVISIONS

ZONE	REV	DESCRIPTION	BY	APPROVED	DATE

NOTES:

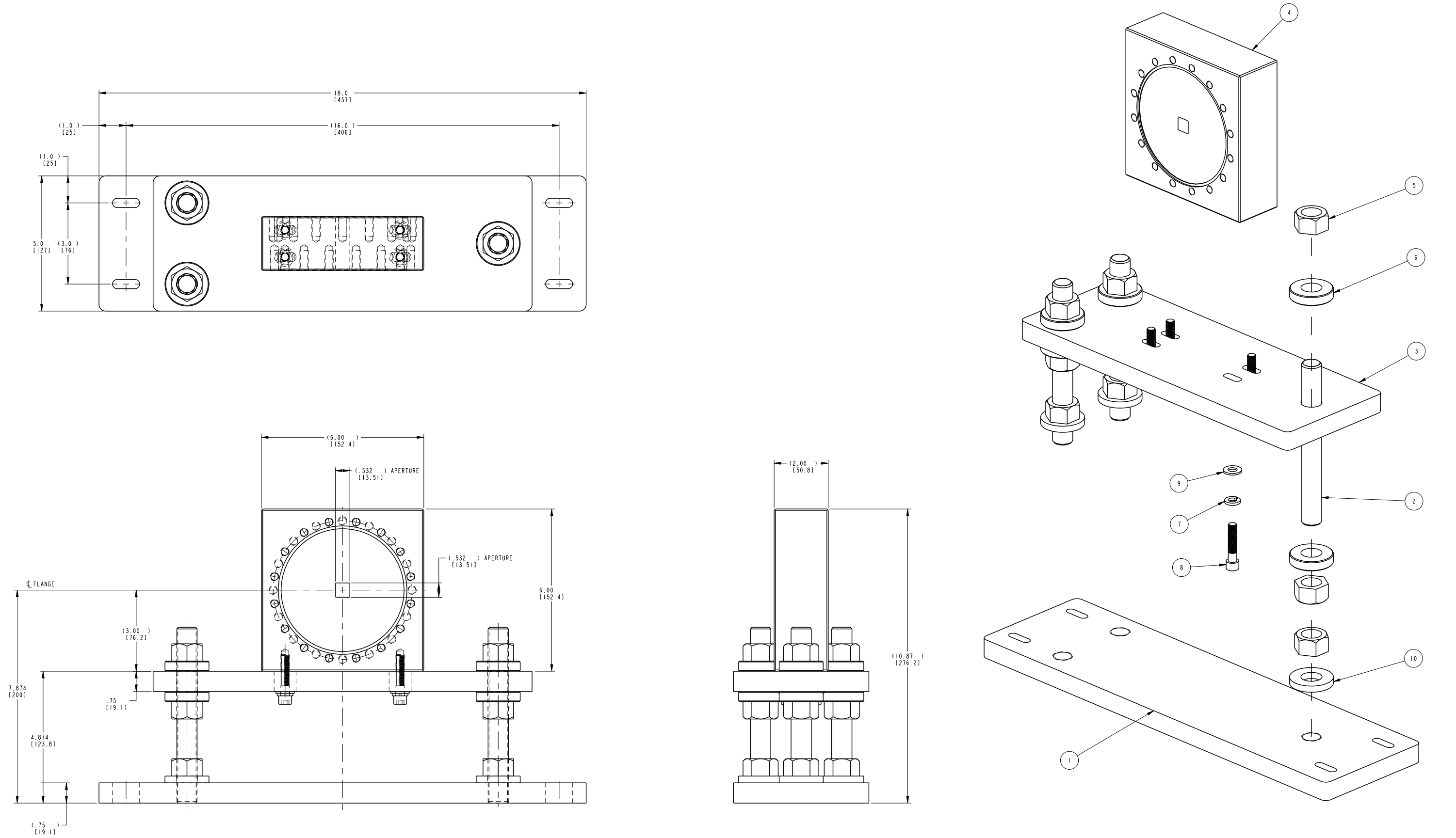
1) CAUTION: HEAVY COMPONENET ESTIMATE WEIGHT: 58 LBS.

2) THIS PART IS INTENDED FOR ULTRA HIGH VACUUM (UHV) SERVICE. THE USE OF SILICONE, SULFUR, PHOSPHOROUS, OR HALOGEN-BASED CUTTING FLUIDS AND ABRASIVES IS PROHIBITED. USE TRIMSOL OR APPROVED EQUIVALENT LUBRICANT. FOR COMPLETE SPECIFICATIONS ON MACHINING, VACUUM REQUIREMENTS, TESTING, AND DELIVERY PREPARATION, SEE ANL DOCUMENT NO. 410201-00095.

3) PROTECT KNIFE EDGES FROM DENTS, NICKS, AND SCRATCHES.

▷ SOURCE OR EQUIVALENT
McMASTER-CARR
P.O. BOX 4355
CHICAGO, IL 60680-4355
630-883-0300

IEX Secondary Bremsstrahlung Collimator 2A



NOTES:

1) CAUTION: HEAVY COMPONENET ESTIMATE WEIGHT: 46 LBS.

2) THIS PART IS INTENDED FOR ULTRA HIGH VACUUM (UHV) SERVICE. THE USE OF SILICONE, SULFUR, PHOSPHOROUS, OR HALOGEN-BASED CUTTING FLUIDS AND ABRASIVES IS PROHIBITED. USE TRIMSOL OR APPROVED EQUIVALENT LUBRICANT. FOR COMPLETE SPECIFICATIONS ON MACHINING, VACUUM REQUIREMENTS, TESTING, AND DELIVERY PREPARATION, SEE ANL DOCUMENT NO. 410201-00095.

3) PROTECT KNIFE EDGES FROM DENTS, NICKS, AND SCRATCHES.

(1) SOURCE OR EQUIVALENT
McMASTER-CARR
P.O. BOX 4355
CHICAGO, IL 60680-4355
630-883-0300

	ITEM	DRAWING / PART NUMBER	REV	NOMENCLATURE OR DESCRIPTION	MATERIAL / SPEC.	QTY
1	10	98125A036	11	WASH FLT 3/4 NOM X 1.63 OD X .25 THK	18-8 SST	3
1	9	98019A385	01	WASH FLT 5/16 x .69 OD x .05 THK	18-8 SST	4
1	8	92196A344	02	SHCS 5/16-24 UNF-3A x 1.50 LG	SST 18-8	4
1	7	92146A030	01	WASH LOCK 5/16 NOM x .58 OD x .09 THK	18-8 SST	4
1	6	91944A490	11	WASH SPHR 3/4 NOM X 1.63 OD X .38 THK	18-8 SST	6
1	5	91845A175	01	NUT HEX 3/4-16 UNF-2B	18-8 SST	9
	4	4105090405-210211	00	BODY, COLLIMATOR (2.00" THICK)	SEE NOTE #2	1
	3	4105090405-210208	00	PLATE, MOUNTING 3/4" THK. X 5.00 W X 14.00 L	PLATE ALUM 6061-T6	1
	2	4105090405-210207	01	STUD, THREADED 3/4-16 UNF X 6 1/2" LONG	18-8 SST	3
	1	4105090405-210205	01	PLATE, SUPT 3/4" THK. X 5.00 W. X 18.00 L.	ALUM 6061-T6	1

PARTS LIST / BILL OF MATERIALS

UNLESS OTHERWISE SPECIFIED ALL DIMENSIONS ARE IN INCHES
TOLERANCES
DECIMALS: .X ± .1, .XX ± .01, .XXX ± .005
ANGULAR: ± 0.5°
SURFACE ROUGHNESS 125

REMOVE ALL BURRS AND BREAK SHARP EDGES .03 MAX. SURFACE TEXTURE IN ACCORDANCE WITH LATEST ASME B46.1-2002 DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH LATEST ASME Y14.5M-1994

MODEL NAME: 4105090405-210210
ELECTRONIC FILE NAME: A4873700

DRAWN BY: N. POINDEXTER — DATE: 19-Mar-12
CHECKED BY: — DATE:
DESIGNED BY: N. POINDEXTER — DATE: 19-Mar-12
RESPONSIBLE ENGINEER: C. BENSON — DATE:
GROUP LEADER: P. DEN HARTOG — DATE:
APPROVED BY: — DATE:
RELEASE LEVEL: RELEASED — MODEL VER: 1 — DRWG VER: 1
MATERIAL: SEE B.O.M. TABLE

THIS DRAWING IS THE PROPERTY OF
Argonne NATIONAL LABORATORY — ADVANCED PHOTON SOURCE

WBS DESCRIPTOR:
EXPERIMENTAL FACILITIES TECHNICAL COMPONENTS
XOR / SRI-CAT BEAMLINES
STANDARD COMPONENTS / COLLIMATORS
BREMSSTRAHLUNG COLLIMATOR

TITLE: ASSEMBLY, 2.00 THICK COLLIMATOR

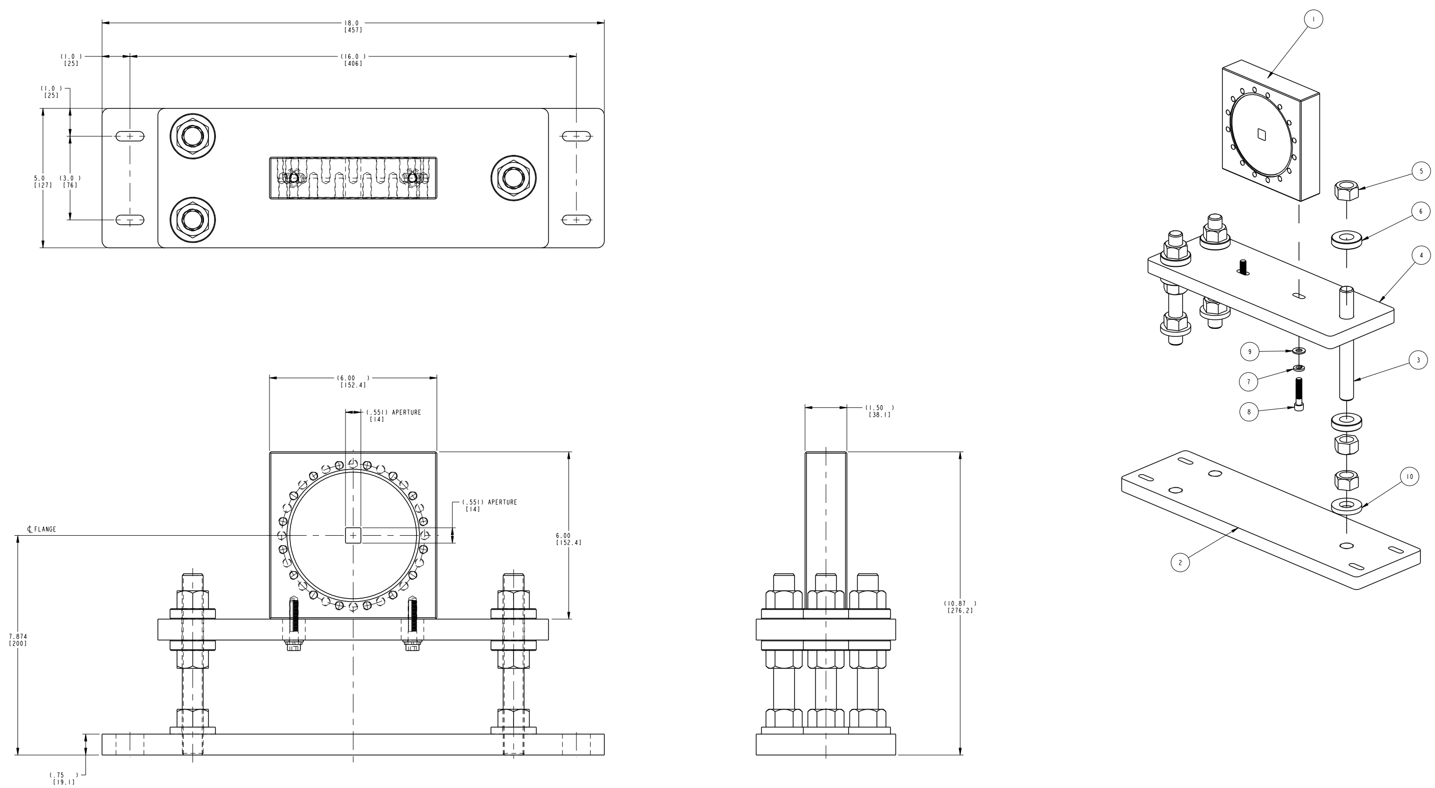
SIZE: E — DRAWING NUMBER: 4105090405-210210 — REV: 00
SCALE: 3:4 — FSCM No: OHRH5 — DO NOT SCALE DRAWING — SHEET 1 OF 1

ZONE	REV	DESCRIPTION	BY	APPROVED	DATE

REVISIONS

IEX Secondary Bremsstrahlung Collimator 3A

ZONE	REV	DESCRIPTION	BY	APPROVED	DATE
	01	SEE DCN # 120501-02	NP		



ITEM	DRAWING / PART NUMBER	REV	NOMENCLATURE OR DESCRIPTION	MATERIAL / SPEC.	QTY
10	98125A036	11	WASH FLT 3/4 NOM X 1.63 OD X .25 THK	18-8 SST	3
9	98019A385	01	WASH FLT 5/16 x .69 OD x .05 THK	18-8 SST	2
8	92196A344	02	SHCS 5/16-24 UNF-3A x 1.50 LG	SST 18-8	2
7	92146A030	01	WASH LOCK 5/16 NOM x .58 OD x .09 THK	18-8 SST	2
6	91944A490	11	WASH SPHR 3/4 NOM X 1.63 OD X .38 THK	18-8 SST	6
5	91845A175	01	NUT HEX 3/4-16 UNF-2B	18-8 SST	9
4	4105090405-210209	00	PLATE, MTG 3/4" THK X 5.00 W X 14.00 L (2-SLOT MTG)	PLATE ALUM 6061-T6	1
3	4105090405-210207	01	STUD, THREADED 3/4-16 UNF X 6 1/2" LONG	18-8 SST	3
2	4105090405-210205	01	PLATE, SUPT 3/4" THK. X 5.00 W. X 18.00 L.	ALUM 6061-T6	1
1	4105090405-210201	01	BODY, COLLIMATOR (1.50" THICK)	SEE NOTE #2	1

PARTS LIST / BILL OF MATERIALS

UNLESS OTHERWISE SPECIFIED ALL DIMENSIONS ARE IN INCHES
TOLERANCES
DECIMALS .X ± .1 .XX ± .01 .XXX ± .005 ANGULAR ± 0.5°
SURFACE ROUGHNESS 125
REMOVE ALL BURRS AND BREAK SHARP EDGES .03 MAX. SURFACE TEXTURE IN ACCORDANCE WITH LATEST ASME B46.1-2002 DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH LATEST ASME Y14.5M-1994

DRAWN BY: N. POINDEXTER	DATE: 01-May-12	THIS DRAWING IS THE PROPERTY OF Argonne National Laboratory	ADVANCED PHOTON SOURCE
CHECKED BY:	DATE:		
DESIGNED BY: N. POINDEXTER	DATE: 01-May-12	WBS DESCRIPTOR: EXPERIMENTAL FACILITIES TECHNICAL COMPONENTS / XOR / SRI-CAT BEAMLINES / STANDARD COMPONENTS / COLLIMATORS / BREMSSTRAHLUNG COLLIMATOR	
RESPONSIBLE ENGINEER: C. BENSON	DATE:		
GROUP LEADER: P. DEN HARTOG	DATE:		
APPROVED BY:	DATE:	TITLE: ASSEMBLY, 1.50" THICK COLLOMATOR	
MODEL NAME: 4105090405-210200	RELEASE LEVEL: RELEASED	MODEL VER: 2	DRWG VER: 2
ELECTRONIC FILE NAME: A4728901	MATERIAL: SEE B.O.M. TABLE	SIZE: E	DRAWING NUMBER: 4105090405-210200, REV. 01
		SCALE: 3:4	FSCM No: 0HRH5 — DO NOT SCALE DRAWING — SHEET 1 OF 1

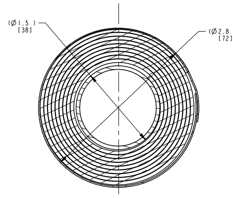
NOTES:
1) CAUTION: HEAVY COMPONENET ESTIMATE WEIGHT: 41 LBS.
2) THIS PART IS INTENDED FOR ULTRA HIGH VACUUM (UHV) SERVICE. THE USE OF SILICONE, SULFUR, PHOSPHOROUS, OR HALOGEN-BASED CUTTING FLUIDS AND ABRASIVES IS PROHIBITED. USE TRIMSOL OR APPROVED EQUIVALENT LUBRICANT. FOR COMPLETE SPECIFICATIONS ON MACHINING, VACUUM REQUIREMENTS, TESTING, AND DELIVERY PREPARATION, SEE ANL DOCUMENT NO. 410201-00095.
3) PROTECT KNIFE EDGES FROM DENTS, NICKS, AND SCRATCHES.

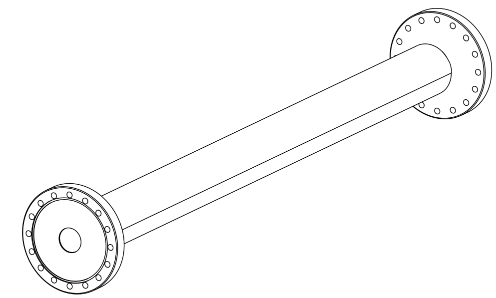
SOURCE OR EQUIVALENT
McMASTER-CARR
P.O. BOX 4355
CHICAGO, IL 60680-4355
630-883-0300

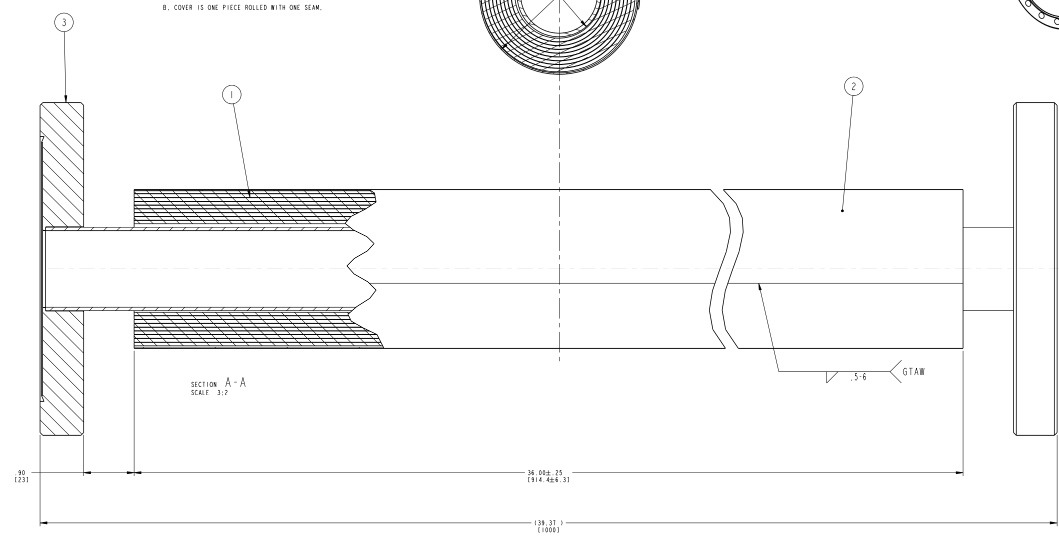
IEX Secondary Bremsstrahlung Shielding-Long

FABRICATION PROCEDURE:

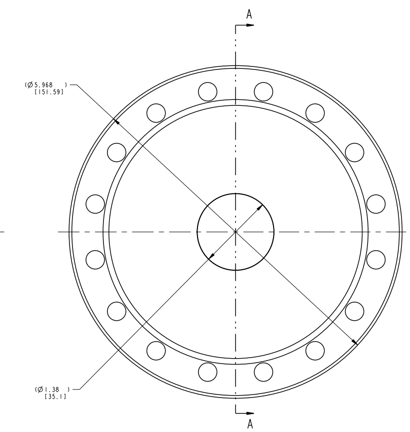
1. A. WRAP EIGHT COMPLETE LAYERS OF LEAD SHEET AROUND VACUUM TUBE WELDMENT. ADD NINTH LAYER AS NEEDED IF SHEET IS UNDERSIZED. TOTAL THICKNESS OF LEAD ALONE MUST BE AT LEAST .5" [13] ALL AROUND.
   B. LEAD SHEET MUST BE ONE CONTINUOUS PIECE AND FREE FROM POROSITY, OXIDE INCLUSIONS, FISSURES AND VOIDS.
2. A. COVER LEAD COMPLETELY WITH SST SHEET (ITEM 3) AND WELD IN PLACE.
   B. COVER IS ONE PIECE ROLLED WITH ONE SEAM.







SECTION A-A
SCALE 3:2



NOTES:

1. DIMENSIONS IN BRACKETS ARE MILLIMETERS AND FOR REFERENCE ONLY.
2. THIS COMPONENT ASSEMBLY IS INTENDED FOR ULTRA HIGH VACUUM (UHV) SERVICE. CONTACT WITH SILICONE, SULPHUR, PHOSPHORUS OR HALOGEN BASED CUTTING FLUIDS AND ABRASIVES IS PROHIBITED. FOR COMPLETE SPECIFICATIONS INCLUDING HANDLING, CLEANING AND DELIVERY PREPARATION, SEE ANL DOCUMENT NO. 410201-00095.
3. LEAD SHEET PER:
   FEDERAL SPEC. NO. QQ-L-201F,
   GRADE 'C' (99.90% PURE LEAD)
4. 24 GA. (.024" THK) 304 SST SHEET, NO. 4 FINISH
5. WEIGHT INCLUDING VACUUM TUBE: 73 LBS.

* DENOTES NO AVAILABLE DRAWING

REVISIONS

ZONE	REV	DESCRIPTION	BY	APPROVED	DATE

	ITEM	DRAWING / PART NUMBER	REV	NOMENCLATURE OR DESCRIPTION	MATERIAL / SPEC.	QTY
	3	4105090601-100101	00	WELDMENT, TRANSPORT TUBE	SEE PARTS LIST	1
*	2	-	00	SHEET, 24 GA (.024" GA. THK)	SEE NOTE #4	1
*	1	-	00	SHEET, LEAD 1/16" THK.	SEE NOTE #3	1

PARTS LIST / BILL OF MATERIALS

UNLESS OTHERWISE SPECIFIED ALL DIMENSIONS ARE IN INCHES
TOLERANCES
DECIMALS .X ± .1 .XX ± .01 .XXX ± .005
ANGULAR ±0.5°
SURFACE ROUGHNESS 125

REMOVE ALL BURRS AND BREAK SHARP EDGES .03 MAX. SURFACE TEXTURE IN ACCORDANCE WITH LATEST ASME B46.1-2002 DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH LATEST ASME Y14.5M-1994

DRAWN BY: N. POINDEXTER	DATE 20-Oct-11	THIS DRAWING IS THE PROPERTY OF	Argonne NATIONAL LABORATORY ADVANCED PHOTON SOURCE
CHECKED BY: C. BENSON	DATE	WBS DESCRIPTOR:	EXPERIMENTAL FACILITIES TECHINACAL COMPONENTS XOR/SRI-CAT BEAMLINES STANDARD COMPONENTS / TRANSPORT TRANSPORT
DESIGNED BY: N. POINDEXTER	DATE 20-Oct-11		
RESPONSIBLE ENGINEER: C. BENSON	DATE		
GROUP LEADER: P. DEN HARTOG	DATE		
APPROVED BY:	DATE	TITLE:	ASSEMBLY, SHIELDED VACUUM TUBE
MODEL NAME: 4105090601-100100	RELEASE LEVEL: RELEASED	MODEL VER: 2 DRWG VER: 2	SIZE: E DRAWING NUMBER: 4105090601-100100 REV. 00
ELECTRONIC FILE NAME: A4813000	MATERIAL: SEE PARTS LIST	SCALE: 3:2 FSCM No: OHRH5	DO NOT SCALE DRAWING SHEET 1 OF 1

IEX Secondary Bremsstrahlung Shielding-Short

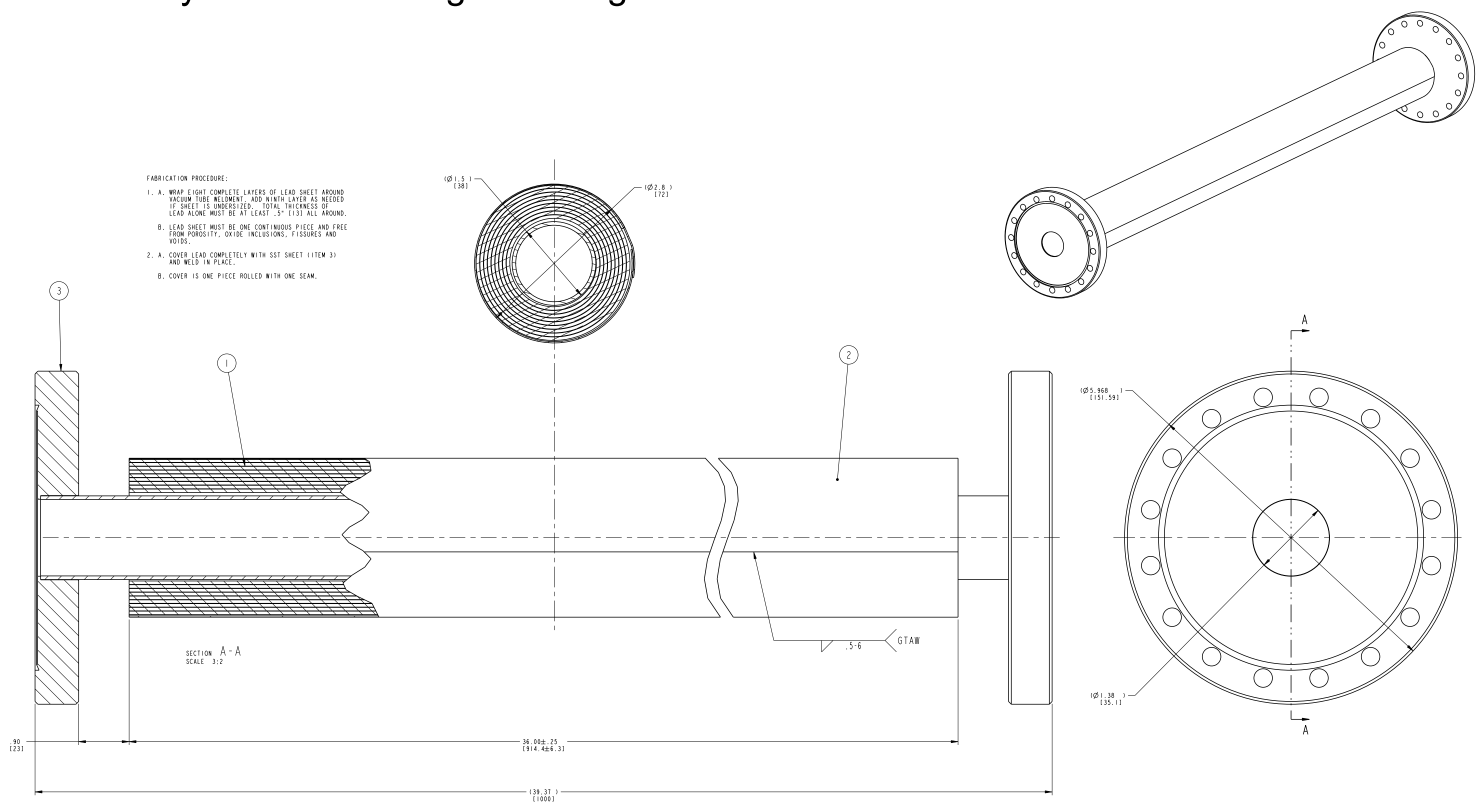
FABRICATION PROCEDURE:

1. A. WRAP EIGHT COMPLETE LAYERS OF LEAD SHEET AROUND VACUUM TUBE WELDMENT. ADD NINTH LAYER AS NEEDED IF SHEET IS UNDERSIZED. TOTAL THICKNESS OF LEAD ALONE MUST BE AT LEAST .5" [13] ALL AROUND.

   B. LEAD SHEET MUST BE ONE CONTINUOUS PIECE AND FREE FROM POROSITY, OXIDE INCLUSIONS, FISSURES AND VOIDS.

2. A. COVER LEAD COMPLETELY WITH SST SHEET (ITEM 3) AND WELD IN PLACE.

   B. COVER IS ONE PIECE ROLLED WITH ONE SEAM.



NOTES:

1. DIMENSIONS IN BRACKETS ARE MILLIMETERS AND FOR REFERENCE ONLY.

2. THIS COMPONENT ASSEMBLY IS INTENDED FOR ULTRA HIGH VACUUM (UHV) SERVICE. CONTACT WITH SILICONE, SULPHUR, PHOSPHORUS OR HALOGEN BASED CUTTING FLUIDS AND ABRASIVES IS PROHIBITED. FOR COMPLETE SPECIFICATIONS INCLUDING HANDLING, CLEANING AND DELIVERY PREPARATION, SEE ANL DOCUMENT NO. 410201-00095.

3. LEAD SHEET PER:
   FEDERAL SPEC. NO. QQ-L-201F,
   GRADE 'C' (99.90% PURE LEAD)

4. 24 GA. (.024" THK) 304 SST SHEET, NO. 4 FINISH

5. WEIGHT INCLUDING VACUUM TUBE: 73 LBS.

* DENOTES NO AVAILABLE DRAWING

	ITEM	DRAWING / PART NUMBER	REV	NOMENCLATURE OR DESCRIPTION	MATERIAL / SPEC.	QTY
	3	4105090601-100101	00	WELDMENT, TRANSPORT TUBE	SEE PARTS LIST	1
*	2	-	00	SHEET, 24 GA (.024" GA. THK)	SEE NOTE #4	1
*	1	-	00	SHEET, LEAD 1/16" THK.	SEE NOTE #3	1

PARTS LIST / BILL OF MATERIALS

UNLESS OTHERWISE SPECIFIED ALL DIMENSIONS ARE IN INCHES
TOLERANCES
DECIMALS: .X ± .1, .XX ± .01, .XXX ± .005
ANGULAR: ±0.5°
SURFACE ROUGHNESS 125

REMOVE ALL BURRS AND BREAK SHARP EDGES .03 MAX. SURFACE TEXTURE IN ACCORDANCE WITH LATEST ASME B46.1-2002 DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH LATEST ASME Y14.5M-1994

DRAWN BY:	N. POINDEXTER	DATE: 20-Oct-11
CHECKED BY:	C. BENSON	DATE:
DESIGNED BY:	N. POINDEXTER	DATE: 20-Oct-11
RESPONSIBLE ENGINEER:	C. BENSON	DATE:
GROUP LEADER:	P. DEN HARTOG	DATE:
APPROVED BY:		DATE:

MODEL NAME: 4105090601-100100
RELEASE LEVEL: RELEASED
MODEL VER: 2
DWG VER: 2
ELECTRONIC FILE NAME: A4813000
MATERIAL: SEE PARTS LIST

Argonne NATIONAL LABORATORY
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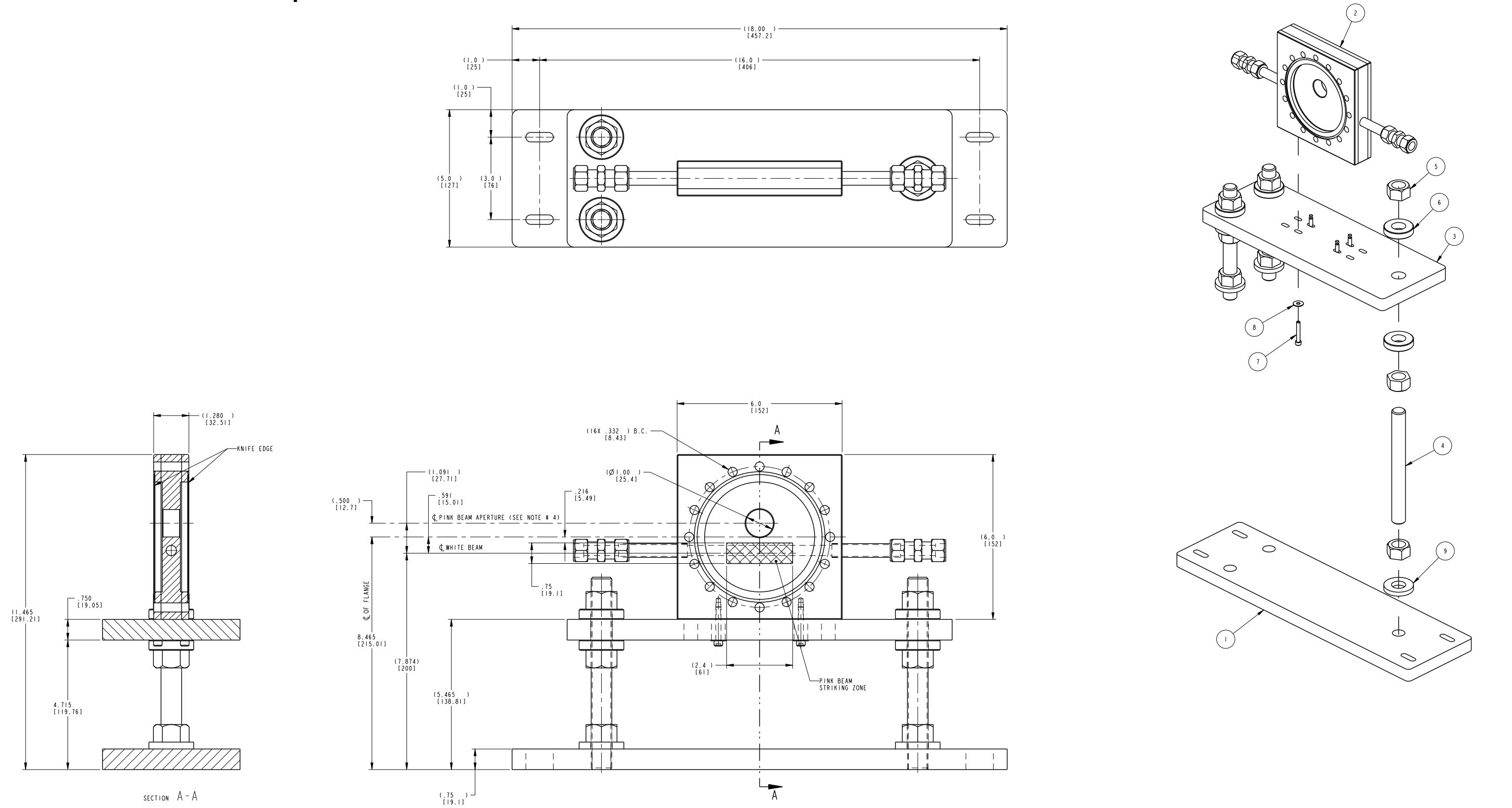
ADVANCED PHOTON SOURCE

WBS DESCRIPTOR:
EXPERIMENTAL FACILITIES TECHINACAL COMPONENTS
XOR/SRI-CAT BEAMLINES
STANDARD COMPONENTS / TRANSPORT
TRANSPORT

TITLE: ASSEMBLY, SHIELDED VACUUM TUBE

SIZE: E
DRAWING NUMBER: 4105090601-100100
REV: 00
SCALE: 3:2
FSCM No: OHRH5
DO NOT SCALE DRAWING
SHEET 1 OF 1

IEX Pink Beam Stop



NOTES:

1) THIS PART IS INTENDED FOR ULTRA HIGH VACUUM (UHV) SERVICE. THE USE OF SILICONE, SULFUR, PHOSPHOROUS, OR HALOGEN-BASED CUTTING FLUIDS AND ABRASIVES IS PROHIBITED. USE TRIMSOL OR APPROVED EQUIVALENT LUBRICANT. FOR COMPLETE SPECIFICATIONS ON MACHINING, VACUUM REQUIREMENTS, TESTING, AND DELIVERY PREPARATION, SEE ANL DOCUMENT NO. 410201-00095.

2) PROTECT KNIFE EDGES FROM DENTS, NICKS, AND SCRATCHES.

3) PINK BEAM MAY NOT BE PERFECTLY LOCATED IN CENTER OF APERTURE.

▷ SOURCE OR EQUIVALENT
McMASTER-CARR
P.O. BOX 4355
CHICAGO, IL 60680-4355
630-883-0300

	ITEM	DRAWING / PART NUMBER	REV	NOMENCLATURE OR DESCRIPTION	MATERIAL / SPEC.	QTY
▷	9	98125A036	00	WASH FLT 3/4 NOM X 1.63 OD X .25 THK	18-8 SST	3
▷	8	92217A445	00	WASHER, FLT #10 SCREW .203 ID X .563 OD	18-8 SST	4
▷	7	92196A276	00	SHCS NO. 10(.190)-32 UNF-3A X 1.25 LG	18-8 SST	4
▷	6	91944A490	00	WASH SPHR 3/4 NOM X 1.63 OD X .38 THK	18-8 SST	6
▷	5	91845A175	00	NUT HEX 3/4-16 UNF-2B	18-8 SST	9
	4	4105091008-100704	00	STUD, THREADED 3/4-16 UNF S/S X 7.00 LG.	18-8 SST	3
	3	4105091008-100702	00	PLATE, MTG. 3/4 X 5.00 X 14.00	ALUM 6061-T6	1
	2	4105091008-100701	00	ASSEMBLY	SEE B.O.M. TABLE	1
	1	4105090405-210205	00	PLATE, SUPT 3/4 X 5 X 18.00	ALUM 6061-T6	1

PARTS LIST / BILL OF MATERIALS

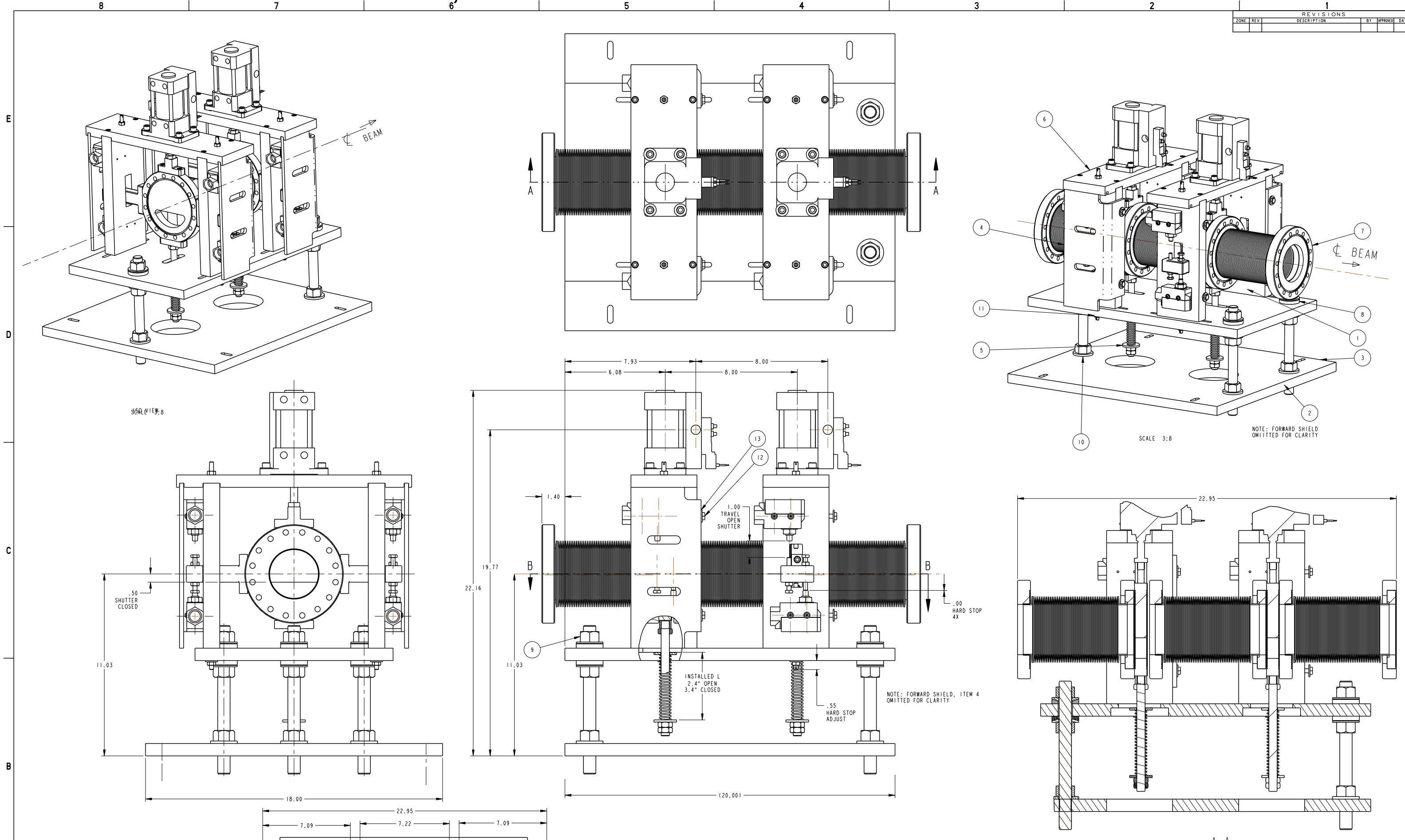
UNLESS OTHERWISE SPECIFIED ALL DIMENSIONS ARE IN INCHES
TOLERANCES
DECIMALS: .X ± .1, .XX ± .01, .XXX ± .005
ANGULAR: ±0.5°
SURFACE ROUGHNESS 125
REMOVE ALL BURRS AND BREAK SHARP EDGES .03 MAX. SURFACE TEXTURE IN ACCORDANCE WITH LATEST ASME B46.1-2002 DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH LATEST ASME Y14.5M-1994

DRAWN BY: N. POINDEXTER	DATE 14-Sep-11	THIS DRAWING IS THE PROPERTY OF Argonne NATIONAL LABORATORY	ADVANCED PHOTON SOURCE
CHECKED BY:	DATE	WBS DESCRIPTOR: EXPERIMENTAL FACILITIES TECHNICAL COMPONENTS XOR/SRI-CAT BEAMLINE STANDARD COMPONENTS / ID SPECIAL FIXED MASK PINK BEAM STOP	
DESIGNED BY: N. POINDEXTER	DATE 14-Sep-11		
RESPONSIBLE ENGINEER: C. BENSON	DATE		
GROUP LEADER: PAT DEN HARTOG	DATE		
APPROVED BY:	DATE	TITLE: ASSEMBLY, PINK BEAM STOP	
MODEL NAME: 4105091008-100700	RELEASE LEVEL: RELEASED	MODEL VER: 0 / DRWG VER: 0	SIZE E / DRAWING NUMBER: 4105091008-100700 / REV. 00
ELECTRONIC FILE NAME: A4759800	MATERIAL: SEE B.O.M. TABLE	SCALE: 3:4 / FSCM No: OHRH5	DO NOT SCALE DRAWING / SHEET 1 OF 1

REVISIONS: ZONE | REV. | DESCRIPTION | BY | APPROVED | DATE

IEX Monobeam Shutters (Shutter-C and Shutter-D)

IEX Monochromatic Beam Shutters C,D



NOTE:
THIS COMPONENT IS PART OF AN ASSEMBLY INTENDED FOR ULTRA HIGH VACUUM (UHV) SERVICE. THE USE OF SILICONE, SULPHUR, PHOSPHORUS OR HALOGEN BASED CUTTING FLUIDS AND ABRASIVES IS PROHIBITED. USE TRIMSOL OR APPROVED EQUIVALENT LUBRICANT. FOR COMPLETE SPECIFICATIONS ON MACHINING, VACUUM REQUIREMENTS, TESTING AND DELIVERY PREPARATION, SEE ANL DOCUMENT NO. 410201-00095.

1 SOURCE OR EQUIVALENT
McMASTER-CARR
P.O. BOX 4355
CHICAGO, IL 60680-4355
630-883-0300

3 SOURCE OR EQUIVALENT
SMC CORPORATION OF AMERICA
858 MERIDIAN LAKE DRIVE
AURORA, IL 60504
630-449-0600

2 SOURCE OR EQUIVALENT
NEWARK ELECTRONICS
1919 S HIGHLAND AVE
LOMBARD, IL 60148-6119
630-317-1000

THIS IS A SKETCH PRINT FOR QUOTATION PURPOSES ONLY
DO NOT TOOL
REVISIONS TO THIS UNISSUED DRAWING WITH THE SK DENOTED WILL BE A LETTER REVISION, I.E. A, B, ETC. WHEN ISSUED FOR TOOLING THE SK WILL BE REMOVED AND THE DRAWING WILL BE ISSUED AT REV '00'

ITEM	DRAWING / PART NUMBER	REV	NOMENCLATURE OR DESCRIPTION	MATERIAL / SPEC.	QTY
13	WASHER_250	00	1/4 STD PLAIN WASHER	STAINLESS STEEL	12
12	HHCS_P25-28_IP25	00	HHCS 1/4-20 UNC-2A X 1.25 LG	STEEL ZINC PLATED	8
11	HEX_NUT_P25-28_	00			4
10	98370A036	01	WASH FLT 3/4 NOM X 1.63 OD X .16 THK	18-8 SST	3
9	91845A175	01	NUT JAM 3/4-16 UNF-2B	18-8 SST	9
8	91131A090	03	WASH SPHR .75 ID X. 1.63 OD X .38 THK	12L14 STEEL	6
7	4105090913-102016	00	BELLOWS ASSEMBLY		3
6	4105090913-102015	00	SHUTTER MOUNT ASSEMBLY	SEE PARTS LIST	2
5	4105090913-102014	00	SPRING ROD ASSEMBLY	SEE PARTS LIST	2
4	4105090913-102013	00	SHEILD	POLYCARBONATE	4
3	4105090913-102012	00	MOUNTING PLATE	6061-T6 ALUMINUM	1
2	4105090913-102007	00	THREADED ROD	18-8 SST	3
1	4105090913-102001	00	MOUNTING PLATE	6061-T6 ALUMINUM	1

PARTS LIST / BILL OF MATERIALS

UNLESS OTHERWISE SPECIFIED ALL DIMENSIONS ARE IN INCHES
TOLERANCES
DECIMALS: .X ± .1, .XX ± .03, .XXX ± .005
ANGULAR: ± 0.5°
SURFACE ROUGHNESS 125
REMOVE ALL BURRS AND BREAK SHARP EDGES .03 MAX. SURFACE TEXTURE IN ACCORDANCE WITH LATEST ASME B46.1-2002 DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH LATEST ASME Y14.5M-1994

DRAWN BY: L.Brown — DATE: 25-Jun-12
CHECKED BY:
DESIGNED BY: T. GRABINSKI — DATE: 25-Jun-12
RESPONSIBLE ENGINEER: C. BENSON
GROUP LEADER: P. DEN HARTOG
APPROVED BY:
MODEL NAME: 4105090913-102000
RELEASE LEVEL: WIP — MODEL VER: 7 — DRWG VER: 7
ELECTRONIC FILE NAME: A4869900
MATERIAL: SEE PARTS LIST

THIS DRAWING IS THE PROPERTY OF Argonne NATIONAL LABORATORY — ADVANCED PHOTON SOURCE
WBS DESCRIPTOR: EXPERIMENTAL FACILITIES XOR/SRI-CAT BEAMLINES STANDARD COMPONENTS SHUTTERS MONO SHUTTER
TITLE: ASSEMBLY
SIZE: E — DRAWING NUMBER: 4105090913-102000 — REV: 00
SCALE: 1:2 — FSCM No: OHRH5 — DO NOT SCALE DRAWING — SHEET 1 OF 1

IEX Beamline Mirrors M0 - M1

Accidental beam mis-steering caused by the supporting hexapods

C. Benson, J. Mc Chesney

June 27, 2011

Mirrors M0 and M1 are supported and aligned with the use of hexapods. The travel range of the hexapods is controlled through limit switches. Absolute control of the travel range is not possible as conventional hard-stops cannot be installed into hexapod systems.

In the absence of hard-stops the reflected beam can be mis-steered horizontally and vertically. Water-cooled masks are installed to prevent the mis-steered beam from striking uncooled components. The masks are strategically placed to allow white and pink beam to pass through, while blocking mis-steered beam from M0 and M1. The minimum power of the intercepted beam is ≥10 Watts.

The shielding configuration consists of two masks; one intercepting the horizontal beam (1A) and a second intercepting the vertical beam (2A) [Fig. 1]. The horizontal range between the white beam and the pink beam is covered by the “White beam stop, Pink beam mask” component, and all beams outboard of this range are protected by the additional horizontal mask.

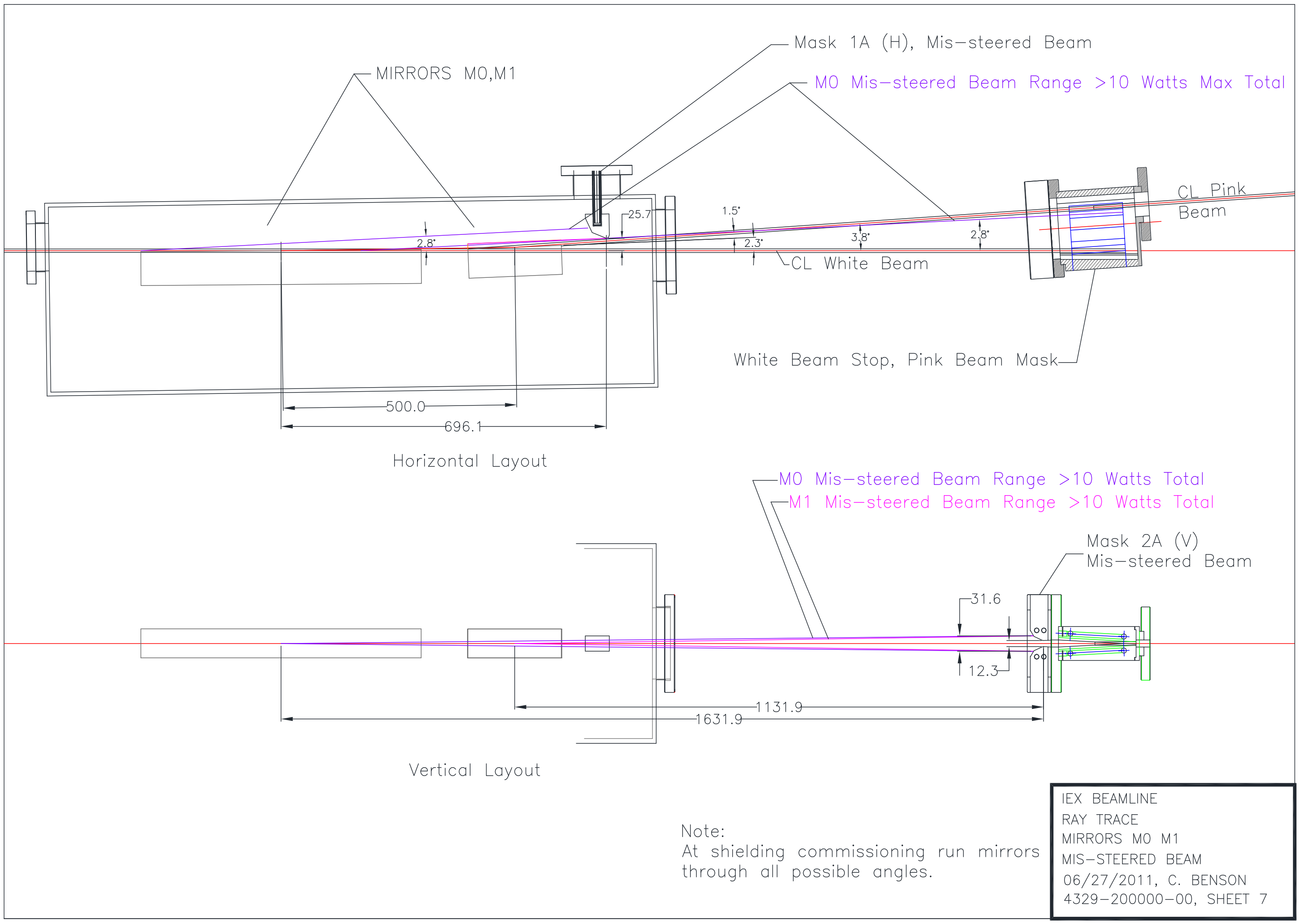
The transmitted power calculations for M0 show that angles of ≤2.8° contain ≥10 Watts [Fig. 2]. The transmitted power for M1 is approximately 25% of M0, which translates into angles of ≤1.38° at ≥10 Watts. As the beamline is configured to operate with the pink beam at a horizontal angle of 1.5°, any mis-stered beam containing ≥10 Watts is within this range. Therefore downstream components do not require any water cooing in the horizontal direction to be protected from the pink beam.

The vertical mis-steering range for M0 is calculated by the using the compound angles of 2.8° and 13° (see Ry below) and a 1630mm distance from the mirror to the mask. The vertical mis-steering range M1 is within the range of the M0 range, and again cooling is not required for vertical M1 mis-steered beam.

XOP software was used to perform the calculations. The undulator power spectrum was calculated using the IEX undulator specifications (a 12.5 mm period length with 38 periods) using a 7.0 GeV ring energy at 200 mA ring current. The most power is produced when running at low energies, high magnetic fields, which corresponded to 250 eV (K=5.27) with a linear horizontal polarization. The reflectivity calculations assumed a Au mirror coating with an RMS roughness of 0.3 nm, corresponding to the specifications outlined in the statement of work for both M0 and M1.

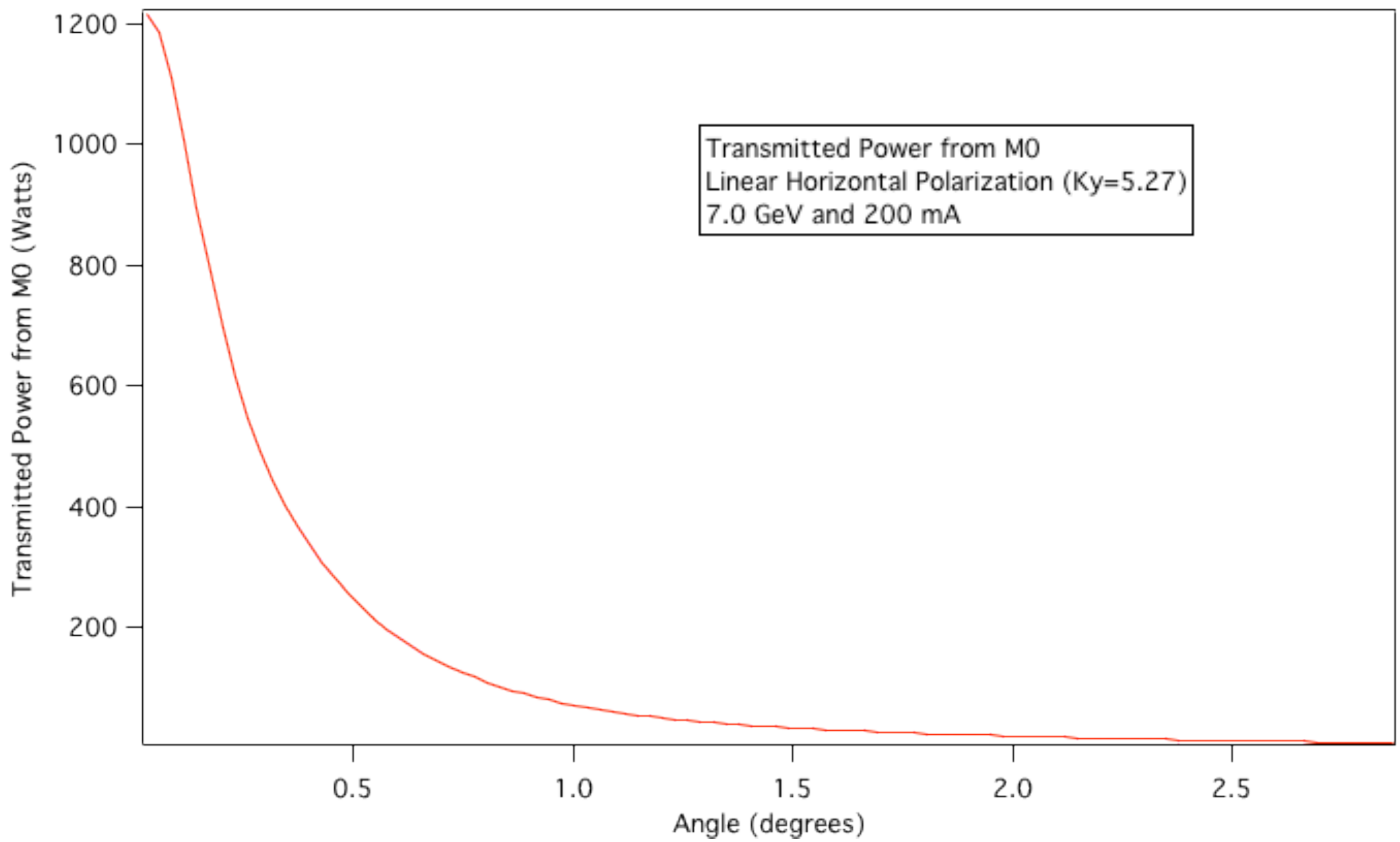
The manufacturer, FMB-Oxford, reports a maximum mis-steering range for the hexapods of Rx=Rz=+/-7degrees and Ry=+/-13degrees. As shown in the power transmission calculations, for "Rx" only the range between 0.1° and 2.8° is applicable. For Ry the entire range is applicable, but the resulting beam striking zone is small due to compound angles.

Thermal analyses will be performed before finalizing the design of the new masks.



[Fig. 1] Shielding configuration

[Fig. 2].



Transmitted Power from M0
Linear Horizontal Polarization (Ky=5.27)
7.0 GeV and 200 mA
Transmitted Power from M0 (Watts)
1200
1000
800
600
400
200
0.5
1.0
1.5
2.0
2.5
Angle (degrees)

From: Roger Dejus <dejus@aps.anl.gov>
Subject: **Re: IEX Mask 1**
Date: July 15, 2011 12:09:02 PM CDT
To: Dana Capatina <capatina@aps.anl.gov>
Cc: "Christa A. Benson" <benson@aps.anl.gov>

Dana and Christa,

I calculated the aperture-limited power and the on-axis power density for linear horizontal polarization mode with the first harmonic energy at 250 eV (worst case scenario) for the IEX 12.5-cm-period EM undulator (L=4.8m, N=38). The effective K value for this energy is 5.27. However, slightly larger K values were used to match the results of the "real" field obtained from magnet modeling for different cases shown here:

Case	K value	Correction Factor
Total Power	5.428	1.03
Aperture Power	5.797	1.10
Power Density	6.008	1.14

An aperture of 5.58 mm (h) x 5.58 mm (v) @ 31.5 m was used, which corresponds to the expected beam size at the location of the pink beam mask (beam size is determined by the fixed mask at 25.4 m). The Au-coated mirror "MO" was assumed to be hit by a missteered photon beam at the very large incidence angle of 1.4 degrees. The larger the incidence angle the lower the high energy cutoff of the mirror - thus this relatively large incidence angle limits the amount of high energy photons passing to downstream components such as the pink beam mask. The mirror energy cutoffs are approx. 20 keV for 0.4 degrees (normal operating condition) and 5 keV for 1.4 degrees for Au coating. (The mirror M1 is assumed not to be in the beam path for the missteered beam.)

Calculated aperture power and on-axis power density for
E1 = 250 eV (lin. hor. polarization) at 7.0 GeV and 200 mA.

```
Total power: 6.4 kW
On-axis power density: 101.6 kW/mrad^2; (= 102 W/mm^2 @ 31.5 m)
```

Aperture power [5.58 mm (h) x 5.58 mm (v)] and on-axis power density at 31.5 m

Quantity	w/o Mirror	w/ Mirror MO @ 1.4 deg.
Power	1735 W	49 W
On-axis power Density	102 W/mm^2	1.5 W/mm^2

Note 1: If the angle of incidence would be smaller than 1.4 degrees, the power and power density after the mirror become higher. For example for the case of using a normal incidence angle of 0.4 degrees the aperture power after the mirror becomes 444 W and the on-axis power density becomes 15.9 W/mm^2. Thus the results are sensitive to the *min* angle of the missteered beam that would cause the beam to hit the pink beam mask. The power density profile was not determined here. One notice however that the profile is not uniform inside the aperture after MO and the power density may in fact be somewhat higher off-axis than on-axis for large misteered angles. But the effect is not particularly large and a uniform profile matching the aperture power may be assumed.

-Roger.

On 7/12/2011 1:56 PM, Dana Capatina wrote:

Hi Roger,

For the IEX beamline, I need to analyze a pink beam mask for thermal and stress performances. The mask is situated at 31.5m, inside the mirror tank.

The components upstream of the pink beam stop we need to account for are:
- 4.5mm X 4.5mm exit mask at 25.4m
- M0, flat mirror, horizontal deflecting, 1.4° at 30.8m; Gold coated; the mirror length = 600mm.

The beam size at the mirror is 5.46mm x 5.46mm and at the mask is 5.58mm x 5.58mm.

The purpose of this mask is to intercept the pink beam for a particular mis-steered beam case, when the angle between the white beam and the mirror is 1.4°. In the normal conditions this angle is 0.4°.

Could you please calculate the total power and the peak power density (W/mm^2) at the mask location for the linear mode horizontal polarization at closed gap and 200 mA?

Thank you very much,
Dana

ICMS # APS_1424159

AES/MED
Engineering Report

Thermal Analysis of the Mask 1A for 29-ID (IEX)

PREPARED BY DANA CAPATINA	Engineer: Dana Capatina GROUP: MED Location: 401/B3208 Lab ext.: 5079 capatina@aps.anl.gov	APPROVED BY	Christa Benson Beamline Lead Engineer Pat Den Hartog MED Group Leader

APPLIES TO

SCOPE OF REPORT

The Mask 1A is situated in the First Optics Enclosure (FOE) inside the M0 and M1 mirrors tank of the new beamline for intermediate energy X-rays (IEX) to be constructed at sector 29-ID. The device will fully intercept the pink photon beam provided by a 12.5 cm period electromagnetic (EM) undulator, passing through the 4.5 mm x 4.5 mm front end exit mask and reflected by the M0 mirror.

The present work will analyze the thermal and stress performances of this mask by using the ANSYS APDL finite element analysis package.

REVIEWED	REVIEW DATE	CHAIRPERSON NAME
ICMS Rev: 2	2011-08-10	

1 Summary

Source:	EM 12.5 cm, 4.8 m @ 10.5 mm gap
	Linear mode horizontal polarization
Total power @ device location :	10 – 186 W
Total peak power density @ device location:	0.32 – 6.00 W/mm^2
Beam current in the analysis:	200 mA
Minimum water flow rate per channel:	2 GPM

2 Reference information and key dimensions

Drawing #:	4105091012-101204
Material:	OFHC Copper
Cooling channel (annulus):	
Dtube out ID:	19.05 mm (.75”)
Dtube in OD:	12.7 mm (.5”)
Heat transfer enhancement insert:	No
Heat transfer coefficient:	0.00386W/mm^2/°C @ 2 GPM/channel
Bulk water temperature:	25.6°C
Cooling wall thickness:	14.2 mm – 20.7 mm
Distance to the center of the straight section:	31.5 m
Source:	EM 12.5 cm, 4.8 m @ 10.5 mm gap
	Linear mode horizontal polarization
Upstream aperture HxV:	4.5 mm x 4.5 mm
Location of the upstream aperture:	25.4 m
Beam size at component HxV:	5.58 mm x 5.58 mm
Total power @ device location:	10 – 186 W (depending on M0 angle)
Peak power density:	0.32 – 6.00 W/mm^2
Mirror reflection, M0:	Horizontal
Mirror shape, M0:	Flat, no focusing
Mirror location, M0:	30.8 m
Mirror optical length, M0:	600 mm
Mirror incidence angle to beam, M0:	0.4 – 2.8 deg. (0.4 deg. nominal)
Mirror surface coating material, M0:	Au

3 Model and mesh

The Mask 1A Pro/E model (4105091012-101204) used for construction is shown in Fig.1.

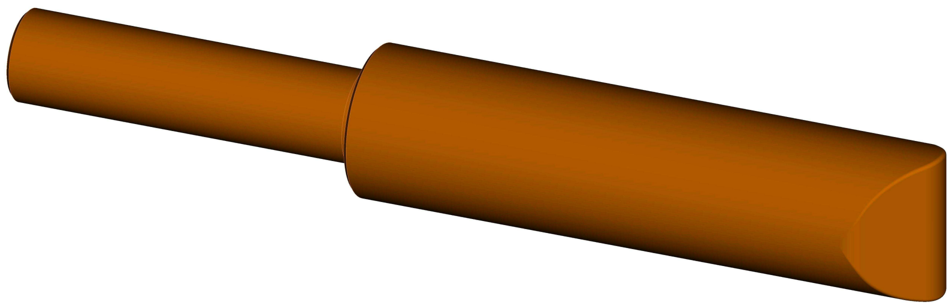


Fig.1 Pro/E assembly model 4105091012-101204, iso view

A simplified geometry as shown in Fig.2 based on the construction model and consisting of the tip of the plunger, 150 mm long, was used in the analysis. Features that are not relevant for this analysis such as external fillets, chamfers, and the internal stainless steel tube were omitted to simplify computation, as they do not affect the analysis results.

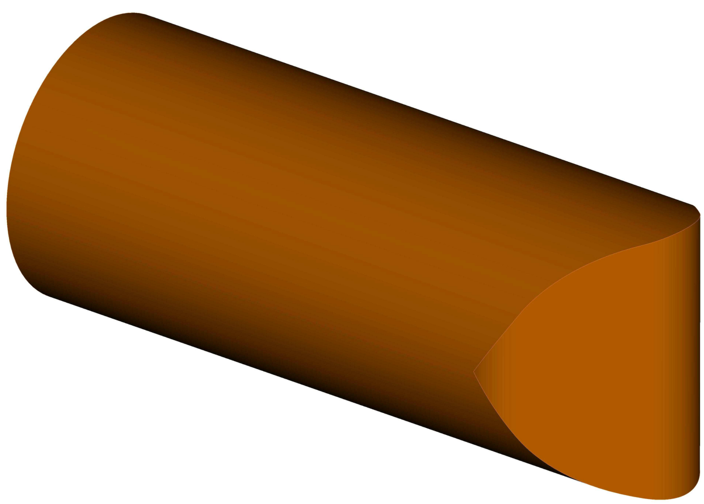


Fig.2 Pro/E model used for the analysis

The ProE model was read into ANSYS APDL for analysis. The volume does not have compatible topology for brick mesh. In order to be able to apply the heat load on brick elements, the intercepting surfaces, as well as the cooling channels, were meshed with very fine Mesh200 quadratic surface elements. The whole volume was then meshed with tetrahedron elements. The total number of nodes was 686,485.

4 Power calculation

The X-ray source in this analysis is an electromagnetic (EM) undulator with 12.5 cm period length and 4.8 m long as described in the MD-TN-2011-001 technical note. The undulator has 38 periods. The linear mode horizontal polarization produces the highest power density and total power out of the possible operation modes, therefore it was the only mode considered in the analysis.

The Mask 1A is intercepting the mis-steered pink beam reflected from the M0 mirror. Therefore the power load on the mask varies with the beam incident angle to the mirror which is in the range of 0.6° to 2.8°. Two cases have been analyzed by this work:

a) Beam incident angle to the mirror 0.695°
This is the case of the minimum beam incident angle to the mirror with the entire beam on the mask, thus the power load on the mask is the highest possible. The power load was calculated by Roger Dejus using XOP. The total power was 186 W and the peak power density was 6 W/mm^2. The power density is nearly uniform and therefore has been applied as a constant on the 5.58 mm x 5.58 mm beam footprint.

b) Beam incident angle to the mirror 1.4°
The power load for this case has been calculated by Roger Dejus using XOP and can be found at APS_1423441. The total power was 49 W and the peak power density was 1.5 W/mm^2. Since XOP does not provide an easy to use power distribution, in order to preserve the total power and the power density the beam footprint was adjusted to 5.72 mm x 5.72 mm.

5 Material properties

The material property needed for the steady state thermal analysis is thermal conductivity (k). The material properties needed for the stress analysis are Young's modulus (E), Poisson's ratio (ν) and the coefficient of thermal expansion (α). The OFHC copper material properties are listed bellow:

k= 0.391 W/mm/°C

E= 115 GPa

ν= 0.323

α= 1.77 x 10^{-5} /°C

6 Boundary conditions

The cooling channel is a concentric tube annulus. The water is supplied to the mask through a stainless steel tube with 12.7 mm (.5") OD. The outer tube ID is 19.05 mm (.75"). The heat transfer coefficient for the concentric tube annulus and 2 gpm water flow rate was 0.00386 W/mm^2/C and it was calculated using Gnielinski correlation for the Nusselt number. The bulk temperature was 25.6°C. Forced convection was applied on the inside of the cooling channel and all other surfaces were assumed adiabatic. For the stress analysis, the body of the beam stop was considered to be simply supported thus the calculated stress is pure thermal stress.

7 Thermal and stress analysis

The ray trace drawing no. 4329-200000-00, sheet 7, provided by Christa Benson was used to determine the beam location on the mask corresponding to a particular beam incident angle to the mirror and vice-a-versa. The beam size at the component was calculated using simple triangle geometry, considering the aperture size and location of the exit mask upstream and the location of the Mask 1A. The beam size was 5.58 mm x 5.58 mm. Two load cases have been analyzed by this work as described above:

a) Beam incident angle to the mirror 0.695°
b) Beam incident angle to the mirror 1.4°

The beam footprint for the two cases is shown in Fig.3.

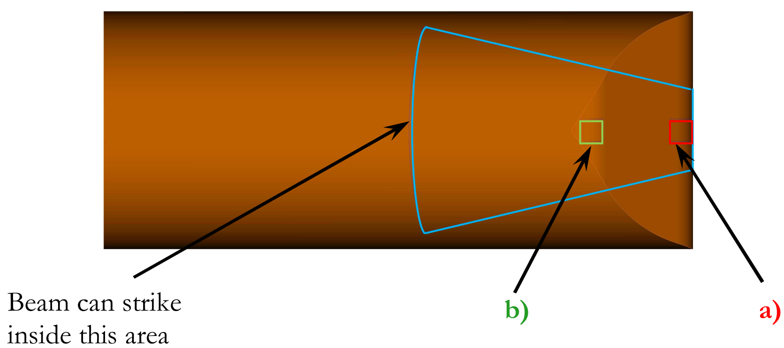


Fig.3 Front view of the Mask 1A, z direction, beam going into the page

After meshing and assigning material properties, the thermal load and boundary conditions were applied. The applied heat flux and resulting temperature distribution in the model for case a) are shown in Fig.4 and 5 respectively and for case b) are shown in Fig. 7 and 8 respectively. For the stress analysis, the load was the temperature distribution determined by the thermal analysis. The Von Mises stress distribution in the model for case a), shown in Fig.6 and for case b) shown in Fig.9 are the results of interest. The maximum temperature and von Mises stress results for both cases are tabulated in Tabel 1.

Heat load case	Beam incident angle (deg.)	Total power load (W)	Heat transf. coef. (W/mm²/C)	Water flow rate (gpm)	T_{max} (°C)	$T_{wall-max}$ (°C)	σ_{vm-max} (MPa)
a)	0.695	186	0.00386	2	76.7	40.4	26.5
b)	1.4	49.0			40.9	29	7.68

Table 1 Temperature and von Mises stress results

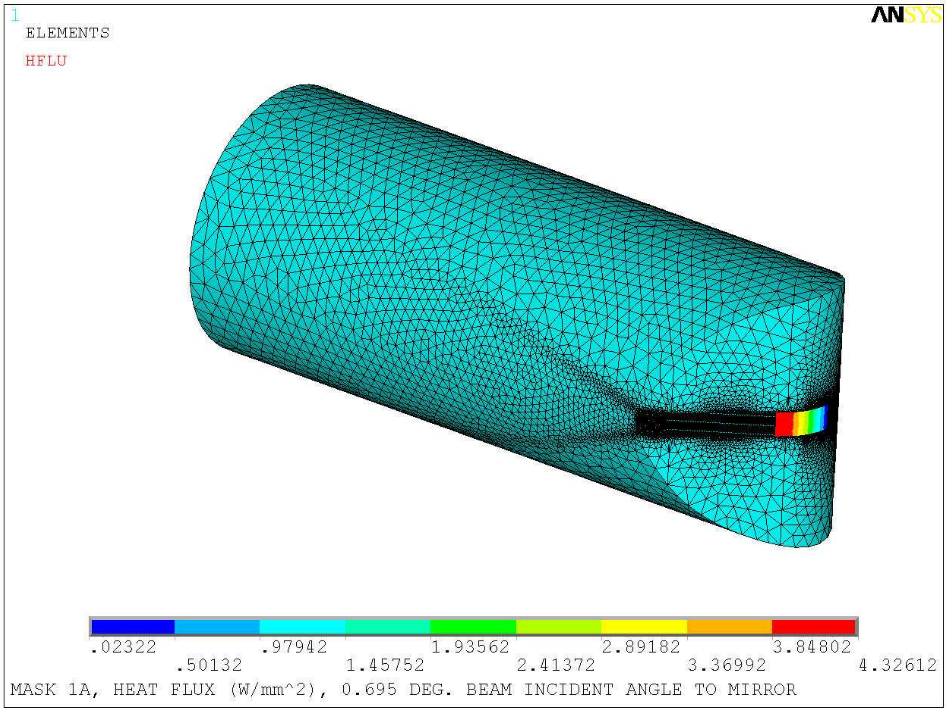


Fig.4 Heat flux distribution, heat load case a)

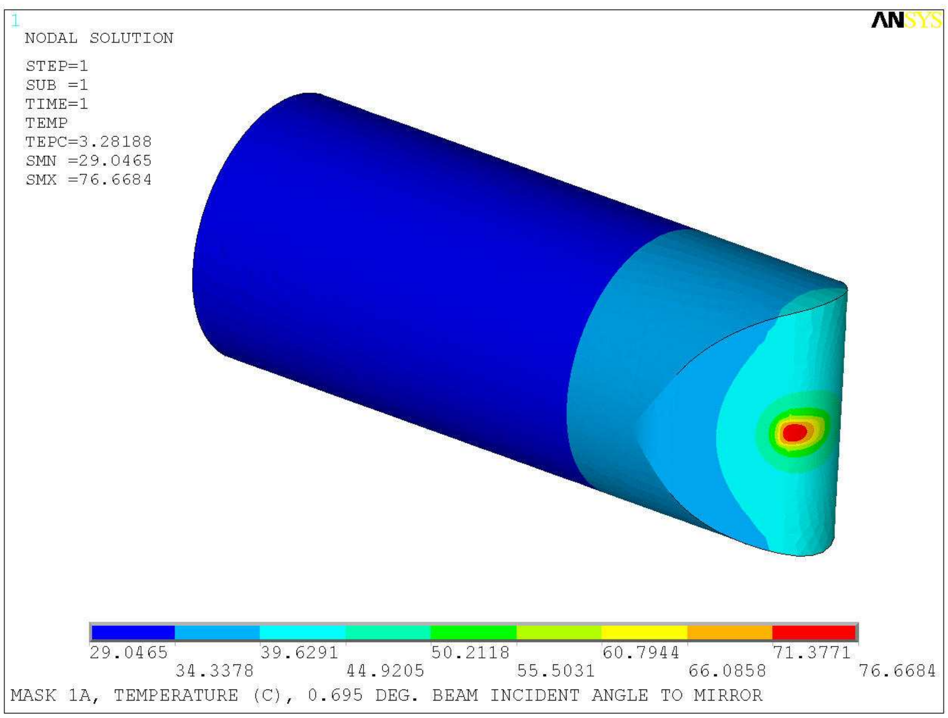


Fig.5 Temperature plot, heat load case a)

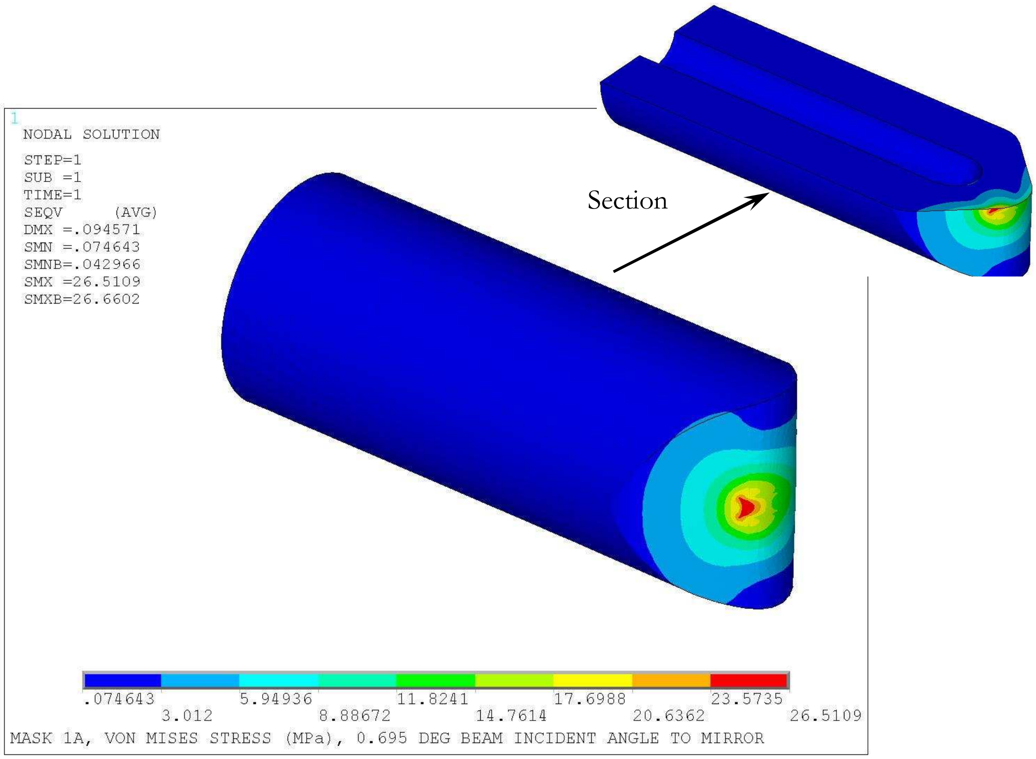


Fig.6 Von Mises stress plot, heat load case a)

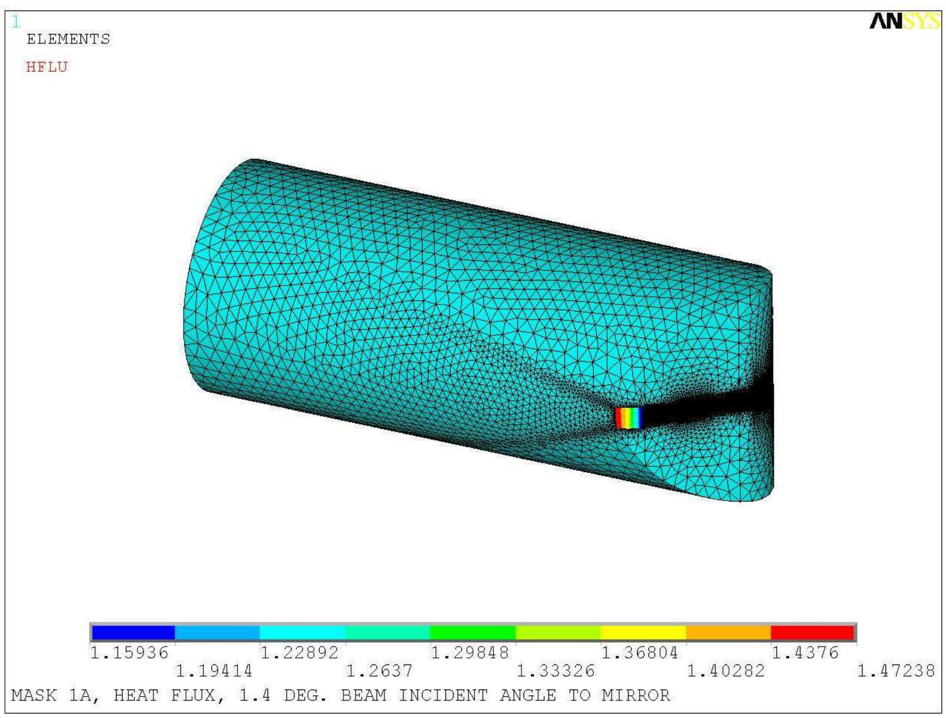


Fig.7 Heat flux distribution, heat load case b)

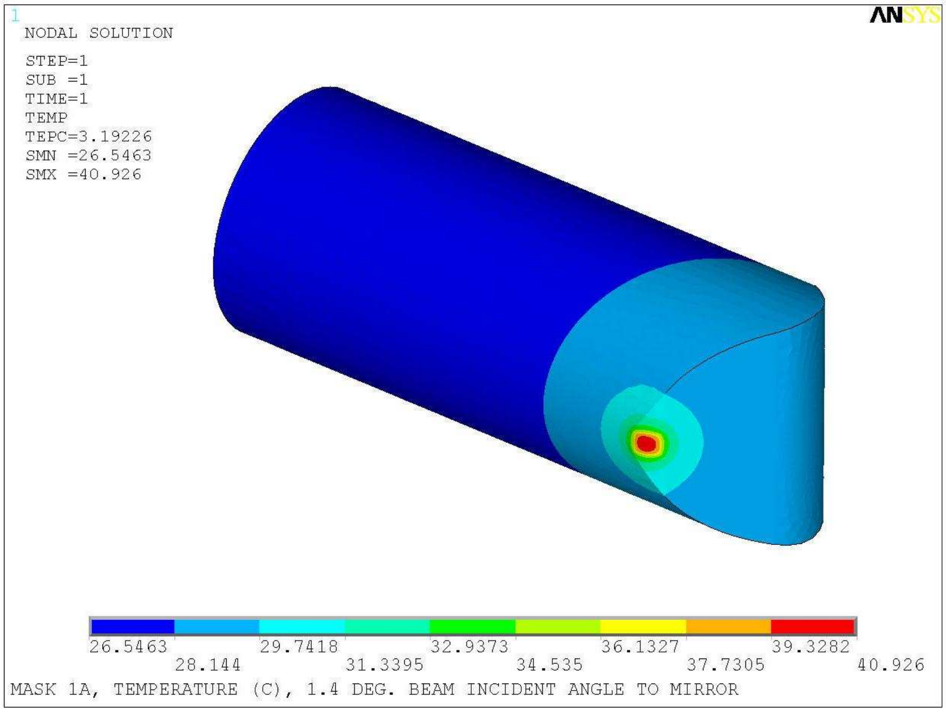


Fig.8 Temperature plot, heat load case b)

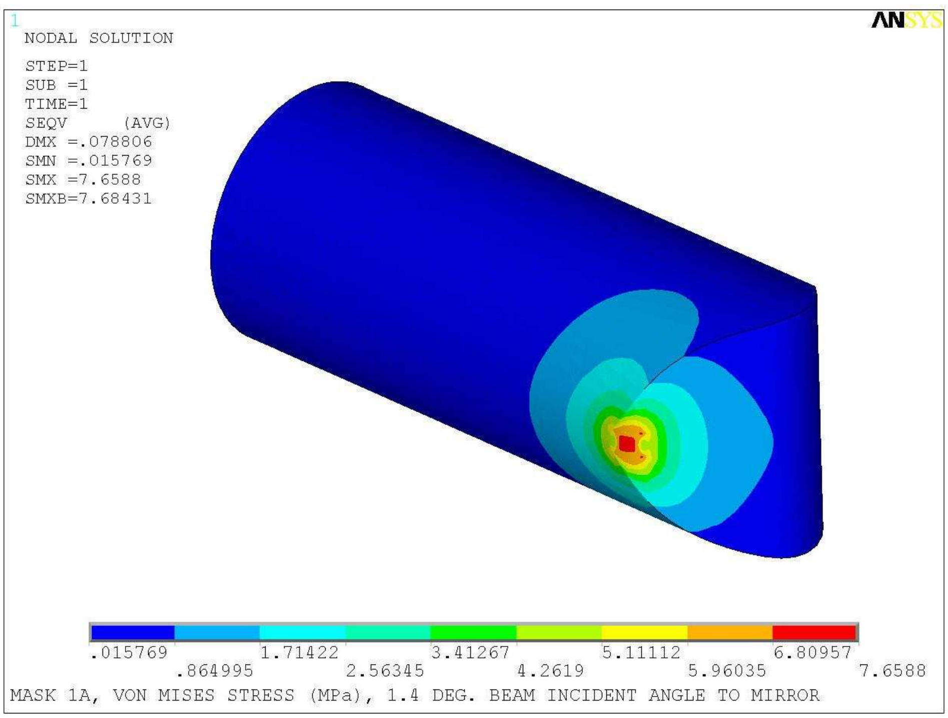


Fig.9 Von Mises stress plot, heat load case b)

8 Result comments

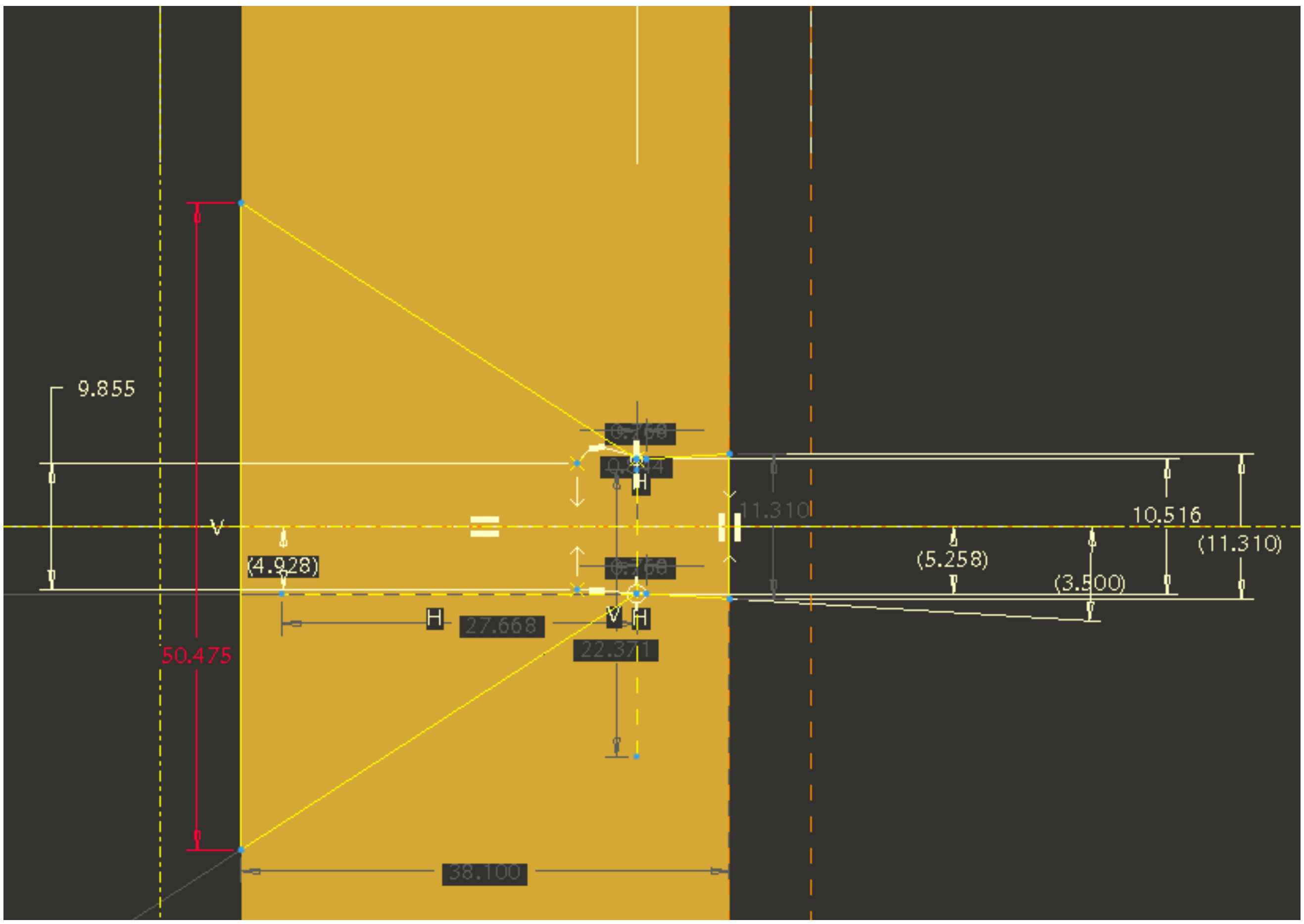
The maximum temperature developed on the mask body is below the APS criteria for OFHC copper of 150°C. The maximum temperature of the cooling walls is well below the boiling temperature of the water at 60 psig. The maximum von Mises stress is much lower than the stress experienced by a typical OFHC copper component in operation at the APS and lower than the yield strength of the annealed copper. Therefore the Mask 1A will perform very well for the conditions considered in this analysis.

Thermal analysis of the modified Mask 2A for IEX beamline as compared to APS_1424160

Summary: The profile of the intercepting surface is modified, cooling channel reduced from 4 to 2, so the water flow rate increased from 0.6 to 1.2 gpm.

Results: Temperatures and stresses are slightly different, but still within the allowable limit for OFHC material.

The modified surface profile:



Three cases of thermal analysis were conducted (same as case a, b, and c in APS_1424160)

The results are listed in the table below:

1. Table from APS_1424160

Heat load case	Deflection angle	Total applied power (W)	Heat transf. coef. ($W/mm^2/C$)	Water flow rate/ channel (gpm)	T_{max} (°C)	$T_{wall-max}$ (°C)	σ_{vm-max} (MPa)
a)	0.57°	80.13	0.0037	0.6	57.6	29.6	24.2
b)	0.70°	287.75			97.5	40.0	71.2
c)	1.28°	239.56			68.4	37.4	47.8

Table 2 Temperature and von Mises stress results

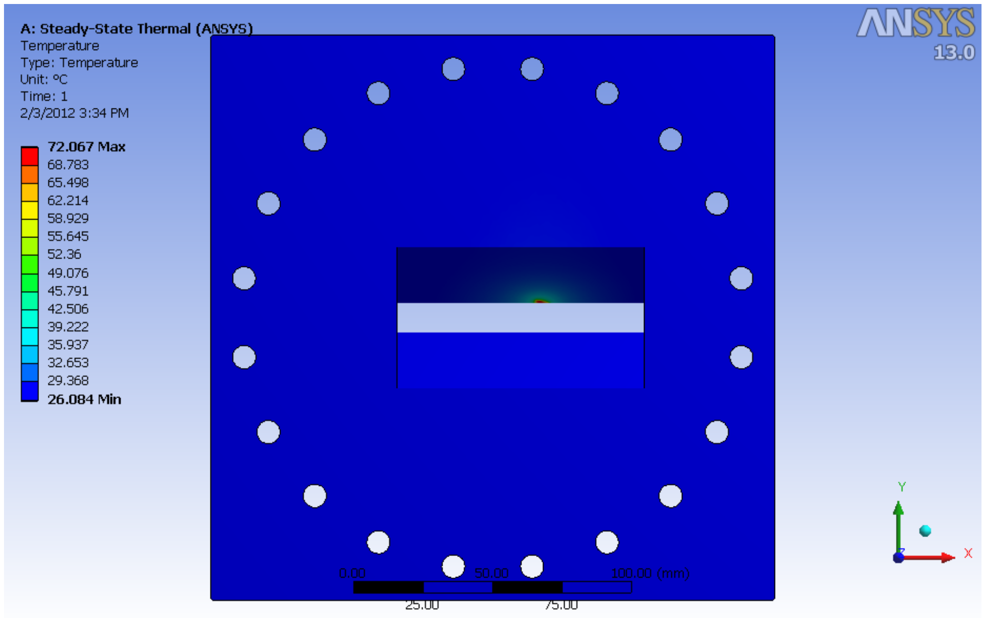
2. Results from the thermal analysis on the modified geometry

Heat load case	Deflection angle	Total Applied power (W)	Heat transf. coef. ($W/mm^2/C$)	Water flow rate/channel (gpm)	T_{max} (C^o)	$T_{wall-max}$ (C^o)	σ_{vm-max} (MPa)
a)	0.57^o	79.541	0.0054	1.2	72	29.9	44.35
b)	0.70^o				116.52	41.5	65.359
c)	1.28^o	235.29			76.53	39.14	45

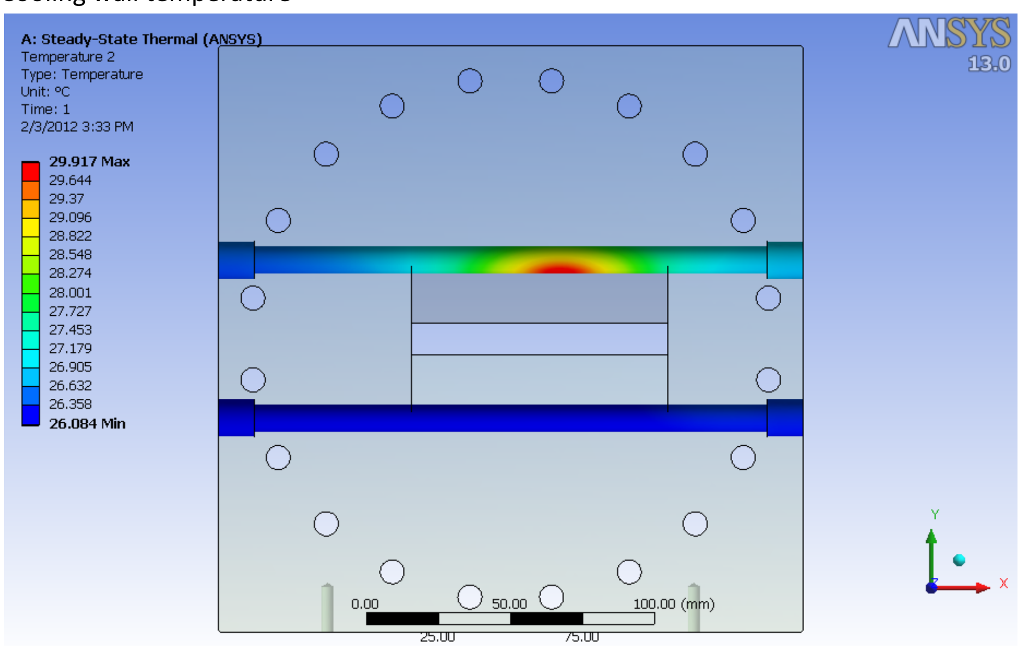
Pictures of the result are attached below:

Case a

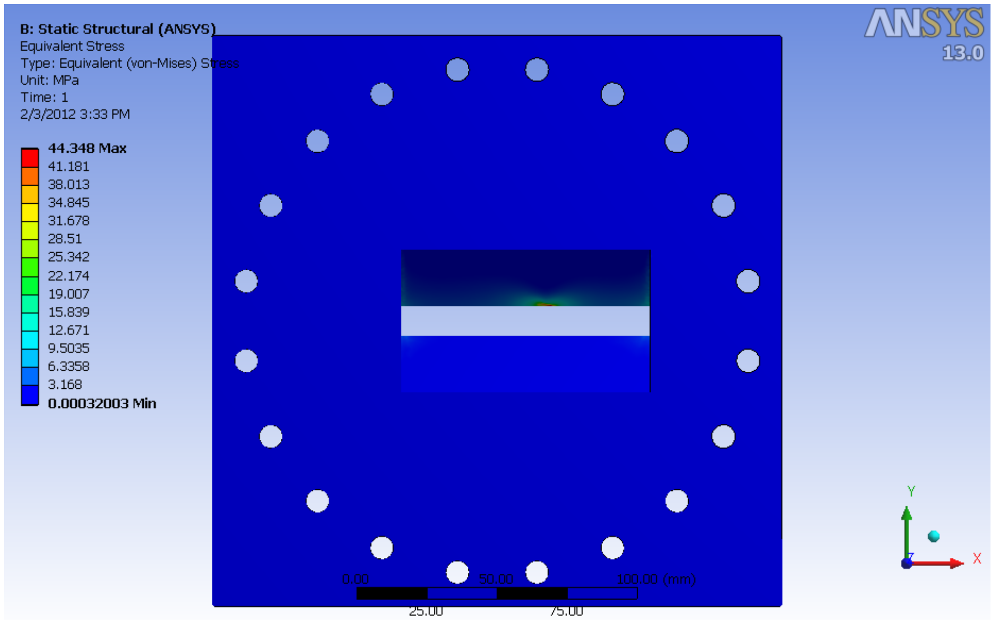
Temperature



Cooling wall temperature

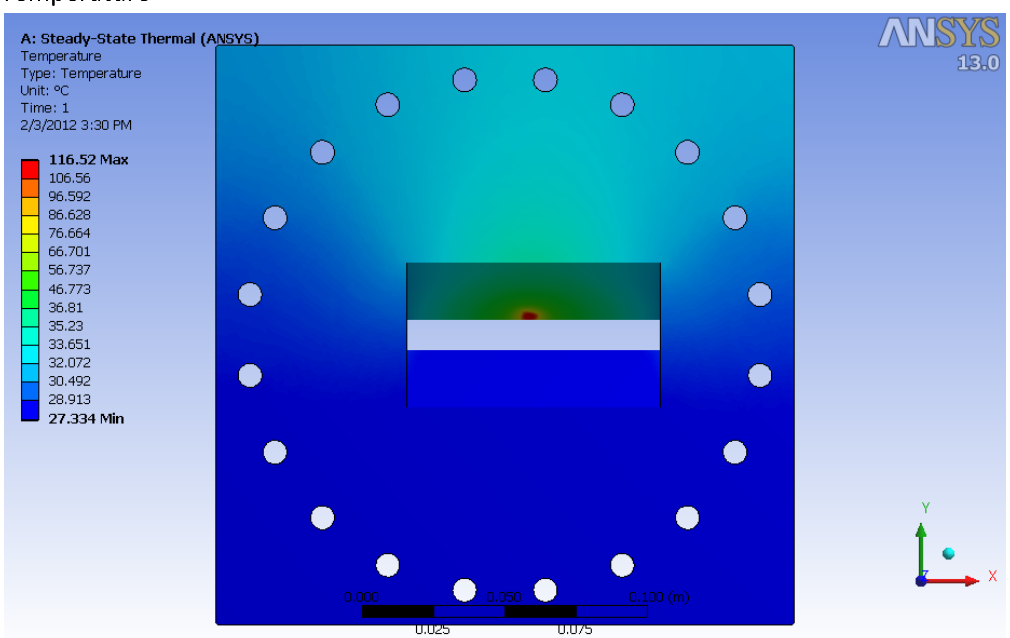


Stress

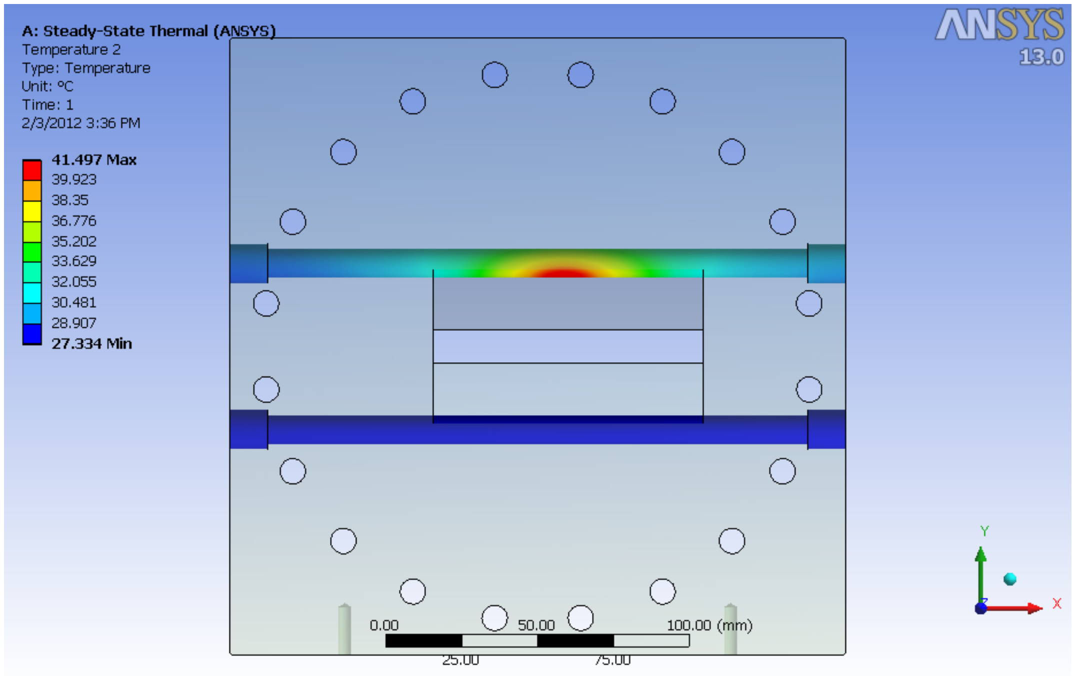


Case b

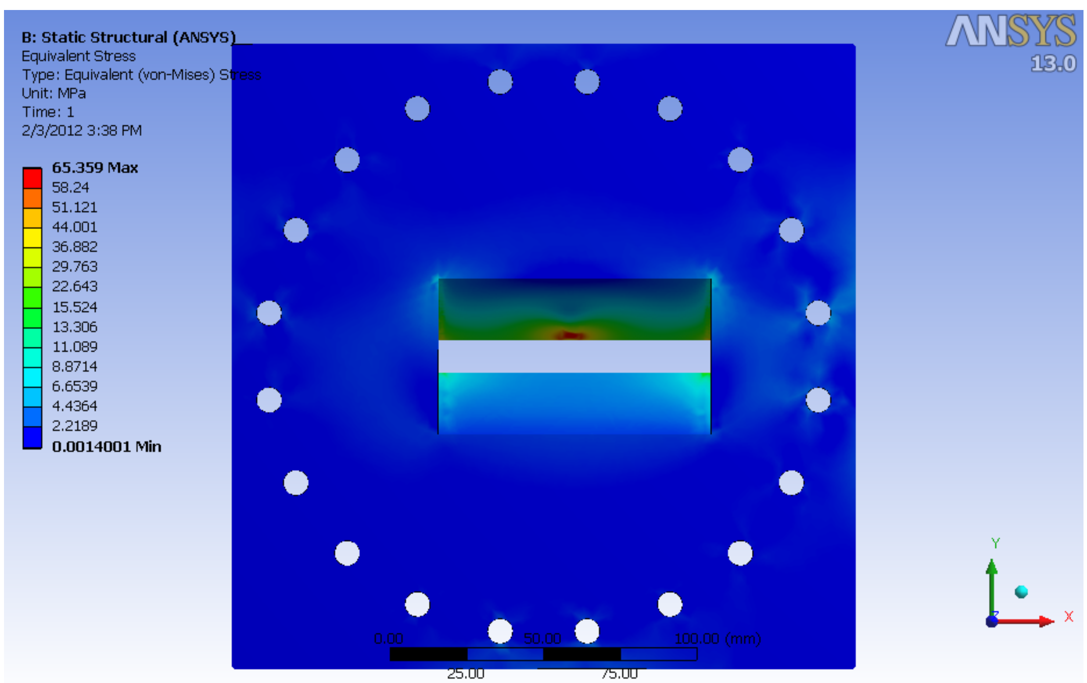
Temperature



Cooling wall temperature

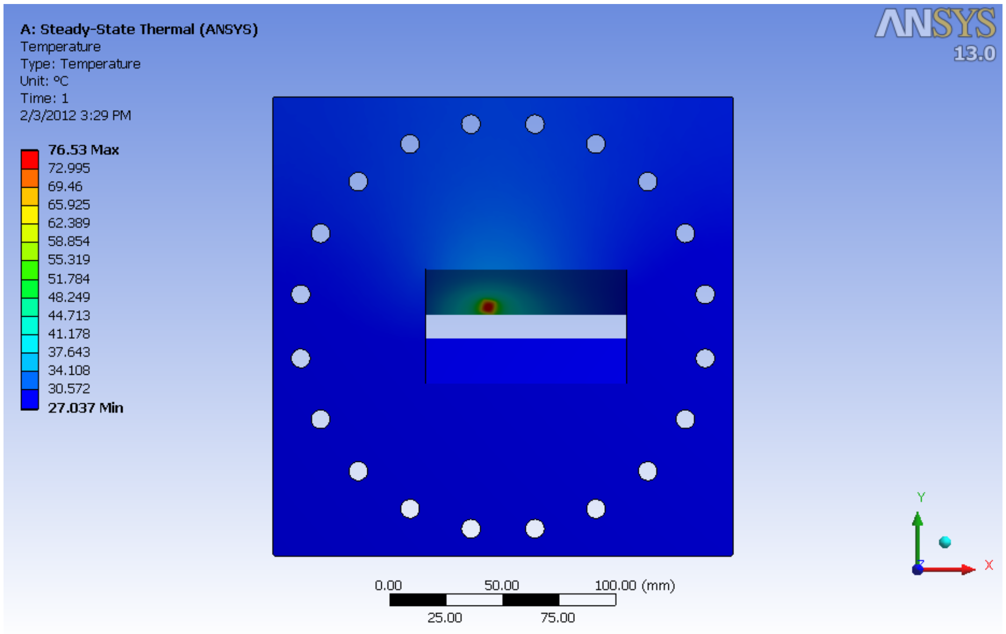


Stress

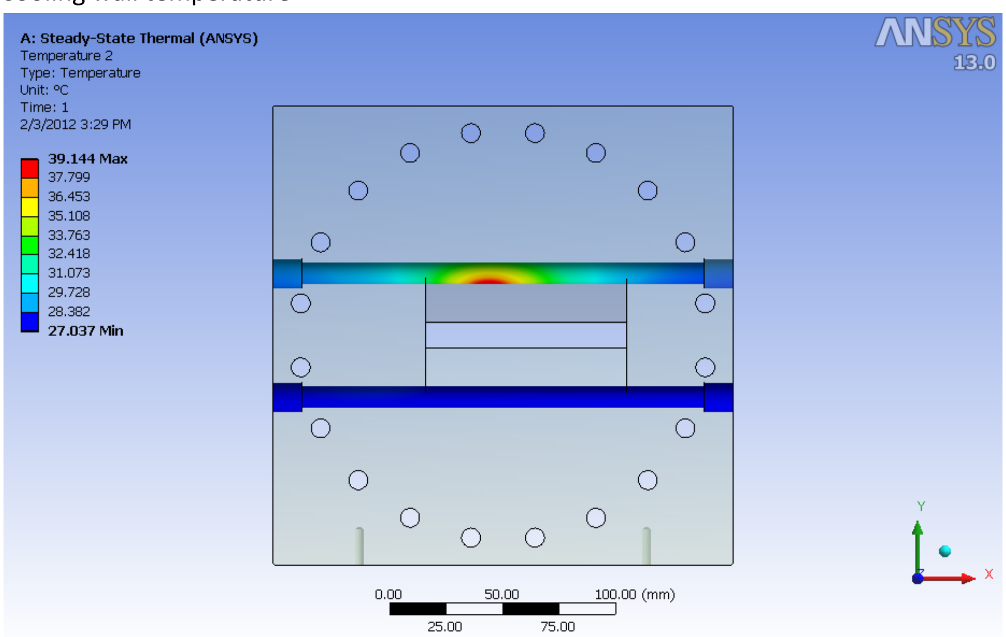


Case c

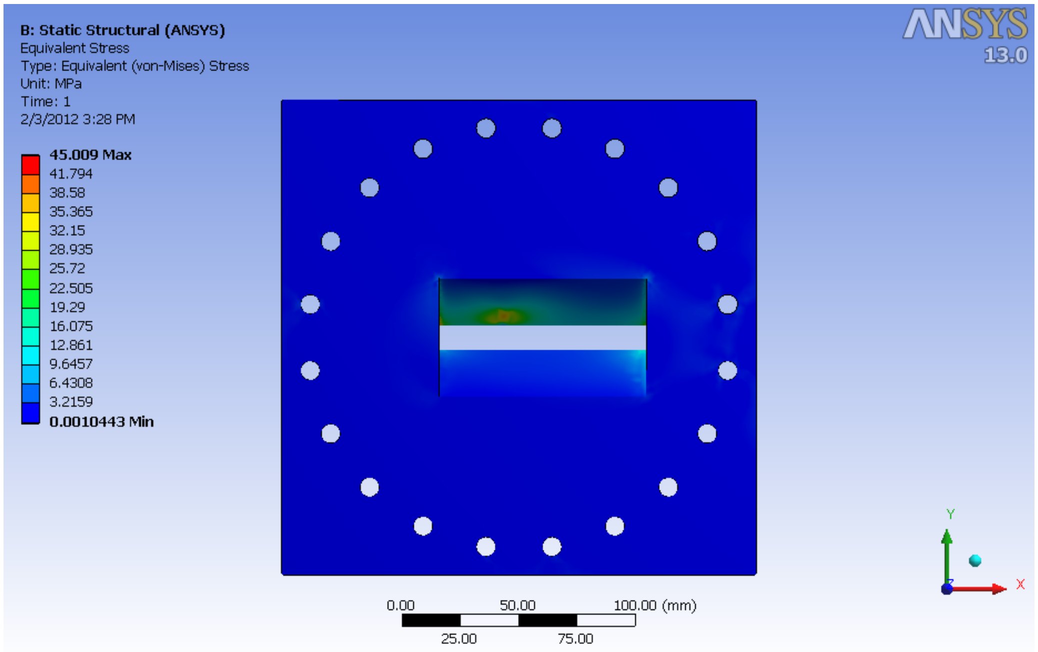
Temperature



Cooling wall temperature



Stress



B: Static Structural (ANSYS)
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1
2/3/2012 3:28 PM
45.009 Max
41.794
38.58
35.365
32.15
28.935
25.72
22.505
19.29
16.075
12.861
9.6457
6.4308
3.2159
0.0010443 Min
ANSYS
13.0
0.00
50.00
100.00 (mm)
25.00
75.00
Y
X

ICMS # APS_1424161

AES/MED Engineering Report

Thermal Analysis of the Mask 3A for 29-ID (IEX)

PREPARED BY DANA CAPATINA	Engineer: Dana Capatina GROUP: MED Location: 401/B3208 Lab ext.: 5079 capatina@aps.anl.gov	APPROVED BY	Christa Benson Beamline Lead Engineer Pat Den Hartog MED Group Leader

APPLIES TO

SCOPE OF REPORT

The Mask 3A is situated in the First Optics Enclosure (FOE) of the new beamline for intermediate energy X-rays (IEX) to be constructed at sector 29-ID. The device will fully intercept the pink photon beam provided by a 12.5 cm period electromagnetic (EM) undulator, passing through the 4.5 mm x 4.5 mm front end exit mask and reflected by one or both of the M0 and M1 mirrors.

The present work will analyze the thermal and stress performances of this mask by using the ANSYS APDL finite element analysis package.

REVIEWED	REVIEW DATE	CHAIRPERSON NAME
ICMS Rev: 3	2011-08-16	

1 Summary

Source:	EM 12.5 cm, 4.8 m @ 10.5 mm gap
	Linear mode horizontal polarization
Total power @ device location :	10 – 31.8 W
Total peak power density @ device location:	0.28 – 0.88 W/mm^2
Beam current in the analysis:	200 mA
Minimum water flow rate per channel:	0.6 GPM

2 Reference information and key dimensions

Drawing #:	TBD
Material:	OFHC Copper
Aperture:	13 mm H x 13 mm V
Cooling channel ID:	7.95 mm (.313")
Heat transfer enhancement insert:	No
Heat transfer coefficient:	0.0037 W/mm^2/°C @ 0.6 GPM/channel
Bulk water temperature:	25.6°C
Cooling wall thickness:	12.7 mm
Distance to the center of the straight section:	33.8 m
Source:	EM 12.5 cm, 4.8 m @ 10.5 mm gap
	Linear mode horizontal polarization
Upstream aperture HxV:	4.5 mm x 4.5 mm
Location of the upstream aperture:	25.4 m
Beam size at component HxV:	6 mm x 6 mm
Total power @ device location:	10 – 31.8 W (dep. on the mirror angle)
Peak power density:	0.28 – 0.88 W/mm^2
Mirror reflection, M0:	Horizontal
Mirror shape, M0:	Flat, no focusing
Mirror location, M0:	30.8 m
Mirror optical length, M0:	600 mm
Mirror incidence angle to beam, M0:	0.4 – 2.8 deg. (0.4 deg. nominal)
Mirror surface coating material, M0:	Au
Mirror reflection, M1:	Horizontal
Mirror shape, M1:	Flat, no focusing
Mirror location, M1:	31.3 m
Mirror optical length, M1:	200 mm
Mirror incidence angle to beam, M1:	1.5 – 2.8 deg. (1.5 deg. nominal)
Mirror surface coating material, M1:	Graphite stripe

3 Model and mesh

The Mask 3A was modeled in Design Modeler, as shown in Fig.1. The simplified geometry consists of a block of 152.4 mm x 152.4 mm x 24 mm. The aperture size is 13 mm x 13 mm. The cooling holes have a 7.95 mm ID and are situated 25.4 mm apart from the horizontal beam plane and 12.7 mm from the mask incident surface. Features that are not relevant for this analysis such as external fillets, chamfers, and counterbores were omitted to simplify computation, as they do not affect the analysis results.

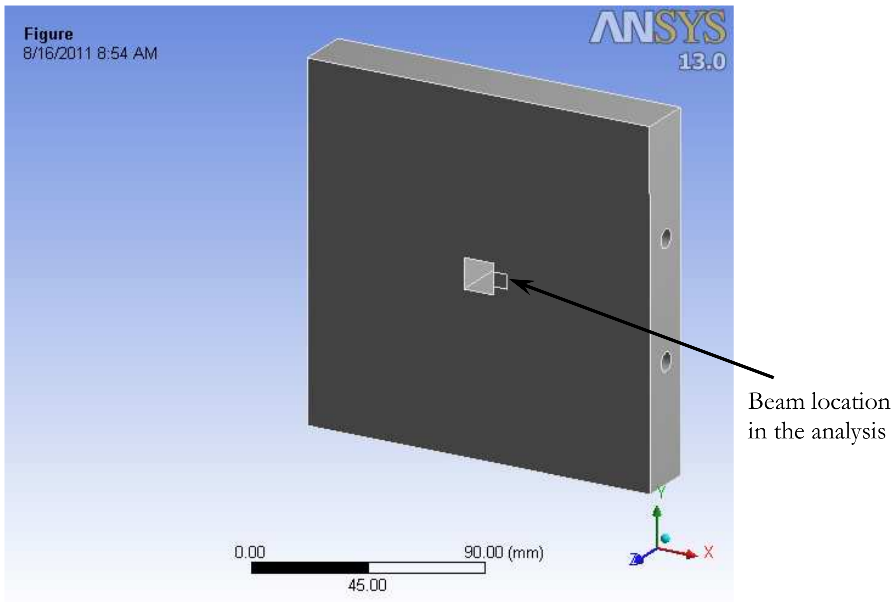


Fig.1 The model used for the analysis

The surface which defines the beam footprint was cut out from the front surface of the mask in order to be able to apply the heat load. The beam footprint size was calculated using simple triangle geometry, considering the aperture size and location of the fixed mask upstream and the location of the Mask 3A. The geometry was then read into ANSYS Workbench. The beam footprint, adjacent surfaces and the cooling channels were finer meshed.

4 Power calculation

The X-ray source in this analysis is an electromagnetic (EM) undulator with 12.5 cm period length and 4.8 m long as described in the MD-TN-2011-001 technical note. The undulator has 38 periods. The linear mode horizontal polarization produces the highest power density and total power out of the possible operation modes, therefore it was the only mode considered in the analysis.

The Mask 3A is intercepting the mis-steered pink beam reflected from either the M0 mirror or the M1 mirror, or both. For conservative reasons only the reflected beam from the M0 is considered in this analysis. The power load on the mask varies with the beam incident angle to the mirror which is in the range of 1.665° to 2.29°.

The ray trace drawing no. 4329-200000-00, sheet 7, provided by Christa Benson was used to determine the beam envelope and the beam location on the mask corresponding to a particular beam incident angle to the mirror and vice-a-versa. Fig.2 shows the beam envelope and characteristic dimensions.

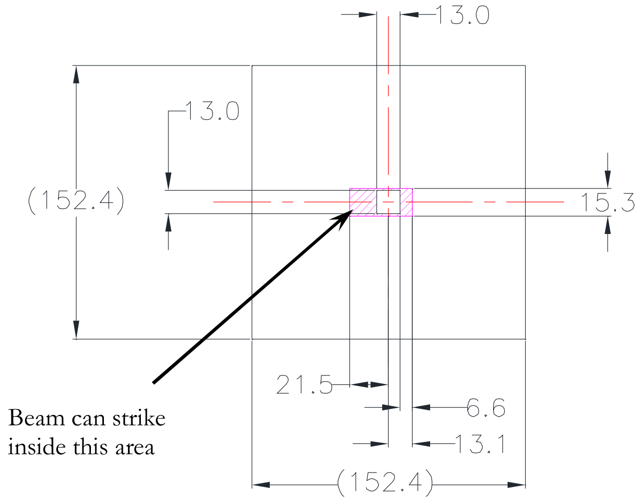


Fig.2 Front view of the Mask 3A, z direction, beam going into the page
Image from the ray trace drawing no. 4329-200000-00, sheet 7

The beam size at the component was 6 mm x 6 mm. The lowest beam incident angle to the mirror which results in the highest heat load on the mask is 1.665°. To simplify the power calculation, the heat load in this analysis was considered as for 1.4° beam incidence, resulting in a conservative approach. The power load was calculated by Roger Dejus for Mask 1A using XOP and can be found at APS_1423441. The total power was 49 W and was distributed uniformly within the beam cross section. A constant heat flux of 1.361 W/mm^2 was applied conservatively on a footprint adjacent to the aperture, as shown in Fig.1.

5 Material properties

The material property needed for the steady state thermal analysis is thermal conductivity (k). The material properties needed for the stress analysis are Young's modulus (E), Poisson's ratio (ν) and the coefficient of thermal expansion (α). The OFHC copper material properties are listed below:

k= 0.391 W/mm/°C

E= 115 GPa

ν= 0.323

α= 1.77 x 10^{-5} /°C

6 Boundary conditions

The cooling consists of two channels running along the aperture, perpendicular to the beam direction. For a plain tube of 7.95 mm (.313") ID and a minimum water flow rate of 0.6 gpm, the heat transfer coefficient calculated using Gnielski (Re<10000) correlation for the Nusselt number was 0.0037 W/mm^2/C. The bulk temperature was 25.6°C. Forced convection was applied on the inside of the cooling channels and all other surfaces were assumed adiabatic. For the stress analysis, the body of the beam stop was considered to be simply supported thus the calculated stress is pure thermal stress.

7 Thermal and stress analysis

After meshing and assigning material properties, the thermal load and boundary conditions were applied. The resulting temperature distribution in the model is shown in Fig.3. For the stress analysis, the load was the temperature distribution determined by the thermal analysis. The Von Mises stress distribution in the model shown in Fig.4 is the results of interest. The maximum temperature and von Mises stress results are tabulated in Tabel 1.

Incident angle	Total applied power (W)	Heat transf. coef. ($W/mm^2/C$)	Water flow rate/ channel (gpm)	T_{max} (°C)	$T_{wall\text{-}max}$ (°C)	$\sigma_{vm\text{-}max}$ (MPa)
0.14°	49.0	0.0037	0.6	41.9	28.0	15.2

Table 1 Temperature and von Mises stress results

8 Result comments

The maximum temperature developed on the mask body is below the APS criteria for OFHC copper of 150°C. The maximum temperature of the cooling walls is well below the boiling temperature of the water at 60 psig. The maximum von Mises stress is much lower than the stress experienced by a typical OFHC copper component in operation at the APS and lower than the yield strength of the annealed copper. Therefore the Mask 3A will perform very well for the conditions considered in this analysis.

9 Mask 4A

The Mask 4A is identical with the Mask 3A and is situated downstream of the later at 35.75 m. The device will fully intercept the pink photon beam provided by a 12.5 cm period electromagnetic (EM) undulator, passing through the Mask 3A aperture and reflected by one or both of the M0 and M1 mirrors. The Mask M4A only intercepts the pink beam for which the white beam incident angle to the M0 mirror is in the range of 1.75° to 2.19°. Because the incidence angles are larger than in the Mask 3A case, there is no need for a FE analysis, the device will perform very well for the conditions specified above.

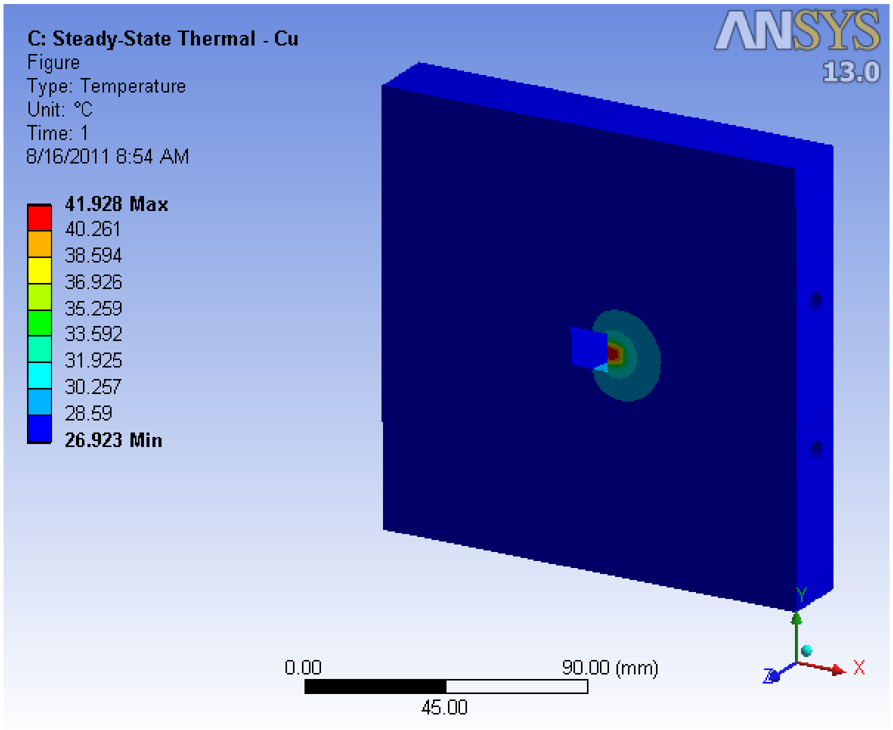


Fig.3 Temperature plot

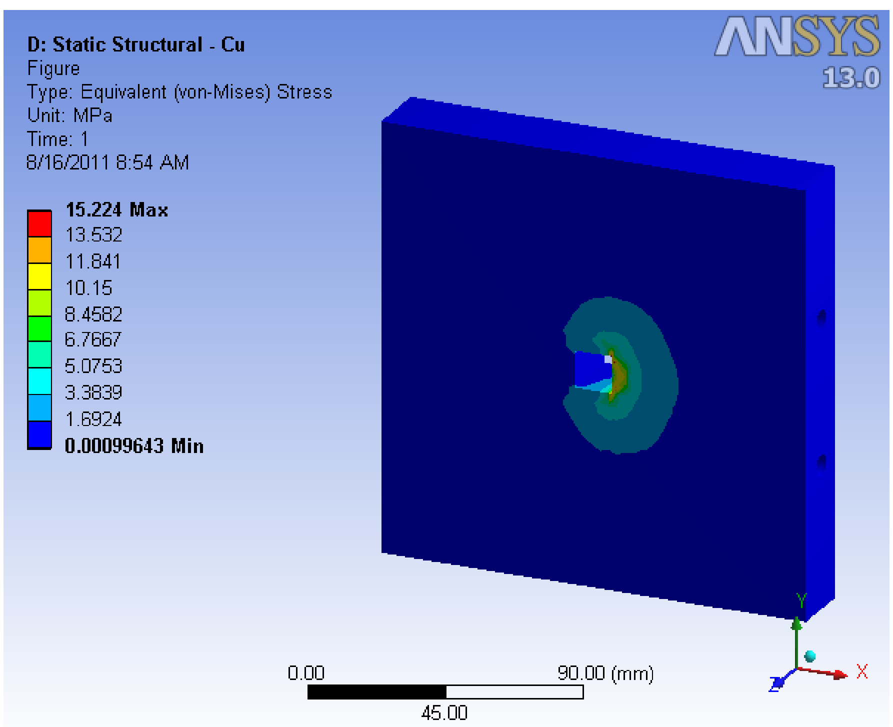


Fig.4 Von Mises stress plot

5/14/12

Sector 29-ID IEX Component Alignment Tolerances

	Item	Comp. Hori. (mm)	Comp. Vert. (mm)	Roll (mrad)	Stroke Distance (mm)	Aperture Nom "In" (mm) (ref)	Aperture Nom "Out" (mm) (ref)	Comp. Length (mm) (ref)	Support Table Hori. (mm)	Support Table Vert. (mm)	Notes
	FOE ("A") **Center Line at 0°**										
1	Slits 1A (H+V)	± 0.25	± 0.25	Best effort	± 4	13x13	1.9x1.9	201+ Bellows (2x)	± 1.5	± 1	Granite table
2	Side Bounce Mirror M0/M1	Best effort	Best effort	Best effort	±25			1390	N/A	N/A	Hexapod
3	Mask 1A (H), missteered beam	± 0.2	± 1	4	0	-25.7	-25.7	~60	In mirror chamber		
4	Supplemental Collimator	± 1	± 1	5	0	105x60	105x60	~70	± 1	± 0.5	06/08/11: Criteria changed, new length TBD
	Center Line at -3.8°H, 0°V - Centerline starts at 31.19482m from Source (This is not the CL Mirror location!)										
5	D1A (Wire)	± 0.25	± 0.25	4	N/A	Ø 160	Ø 160	190	± 1	± 0.5	
6	Mask 2A (V), missteered beam	± 1	± 0.25	4	0	40	12.3	50.8	± 1	± 0.5	
7	White Beam Stop/Pink Beam Mask	± 0.25	± 0.25	4	0	47 x 12	6.5 x 6.5	220.3	± 1	± 0.5	
8	Primary Bremstrahlung Stop	± 2	± 2	5	0	N/A	N/A	300+	± 1	± 0.5	(Pb)
9	D2A (W,Mesh) (DiaGon)	± 0.5	± 0.5	5	N/A	Ø 100	Ø 100	269.8	± 1	± 0.5	
10	Secondary Bremstrahlung Collimators	± 0.5	± 0.5	N/A	0	Ø 13/14	Ø 13/14	70	± 2.5	± 0.5	(W/SS)
	APS Floor ("B") **Center Line -3.8°H, 0°V - Centerline same as above**										
11	Mirror/Monochromator M2+Grating	Best effort	Best effort	Best effort							
	Center Line -3.8°H, +0.8°V - Centerline starts at 40.77455m from Source (This is not the CL Monochromator location!)										
12	D3B (YAG/Au Mesh)	± 1	± 1	N/A	N/A	Ø 100	Ø 100	269.8			TBD
13	Slits 2B (H)	± 0.25	± 1	Best effort	TBD	TBD	TBD	TBD	± 1.5	± 1	
14	Pink Beam Stop	± 0.5	± 0.5	N/A	0	Ø 25.4*	Ø 25.4*	50.8	± 1	± 0.5	*Aperture for Mono Beam
15	Mirror M3R (H)	Best effort	Best effort	Best effort	TBD						"Z" support ± 1.5?
16	D4CD (YAG)	± 0.5	± 0.5	N/A	N/A	Ø 100	Ø 100	269.8			
	ARPES Beamline ("C") - Centerline same as above										
17	Shutters C (Mono)	± 0.25	± 0.25	N/A	1	Ø 25.4		19+ Bellows (2x)	± 1	± 0.5	
18	D5C (YAG)	± 2.5	± 2.5	N/A	N/A	Ø 100	Ø 100	269.8			
19	Slits 3C (V)	± 1	± 0.25	Best effort	N/A	TBD	TBD	TBD	± 1.5	± 1	
20	Gas-Cell (Tee)	± 2.5	± 2.5	N/A	N/A	Ø 35	Ø 35	125	± 2.5	± 0.5	
21	Mirror M3A (H)	Best effort	Best effort	Best effort	TBD						
	Center Line -6.8°H, +0.8°V - Centerline starts at 64.3m from Source										
22	Mirror M4A (V)	Best effort	Best effort	Best effort	TBD						
	Center Line -6.8°H, -2.2° V - Centerline starts at 65.1m from Source										
23	D6C (YAG/Au Mesh/Diode)	± 2.5	± 2.5	N/A	N/A	Ø 100	Ø 100	269.8			
24	ARPES Endstation	Best effort	Best effort	Best effort							
	RSXS Beamline ("D")										
	Center Line -1.3°H, +0.8°V - Centerline starts at 43.7m from Source										
25	Shutters D (Mono)	± 0.25	± 0.25	N/A	1	Ø 25.4		19 + Bellows (2x)	± 1	± 0.5	
26	D5D (YAG)	± 1	± 1	N/A	N/A	Ø 100	Ø 100	269.8			
27	Slits 3D (V)	± 1	± 0.25	4	TBD	TBD	TBD	254	± 1.5	± 1	Granite table
28	Mirror M4R (V)	Best effort	Best effort	Best effort	?						
	Center Line -1.3°H, -1.7°V - Centerline starts at 64.7m from Source										
29	D6D (YAG/Au Mesh/Diode)	± 1	± 1	N/A	N/A	Ø 100	Ø 100	269.8			
30	RSXS Endstation	Best effort	Best effort	N/A							
31	Gate Valve, 6"CF (V1,2)	± 2.5	± 2.5	N/A	N/A	Ø 100	Ø 100	70	± 2.5	± 0.5	
32	Gate Valve, 4.5"CF (V3,4,5,7,8,9,10,11,12)	± 2.5	± 2.5	N/A	N/A	Ø 63	Ø 63	70	± 2.5	± 0.5	
33	Gate Valve, 2.75"CF (V6A,V6R, Gas-Cell)	± 1.5	± 1.5	N/A	N/A	Ø 40	Ø 40	35	± 2.5	± 0.5	

Unless otherwise noted, components are centered around beam axis
Z-locations are along 0° Axis
Z-direction - Support table tolerances: Basic Steel ±5mm, Granite ±3mm, Hexapods: ±3mm, Conventional mirror supports: ±3mm
x/y/z positions are listed on the assembly drawings to avoid miscomunication

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Power absorbed by the IEX optical elements

Prepared by:
Ruben Reininger
(Dated: December 1, 2009)

We summarize our calculations of the power absorbed by the first four optical elements of the IEX beamline under several insertion device (ID) conditions. The ID has 38 periods of 12.5 cm and the stored current in the ring is assumed to be 0.2 A. The numerical results for each one of the cases described below has been sent with this report as excel files for finite element analysis (FEA). The first row and first column in the excel tables give the mirror coordinates in mm and their intersection gives the corresponding absorbed power density in W/mm^2.

The total power and power density were calculated using the SRCalc code [1] at several photon energies for the three gratings planned for the monochromator. The parameters of the machine and the insertion device used in the calculations are given in Table I. We have assumed a 12.5 cm period device and increased the current to 200 mA. The beamline acceptance was taken as 4.5×4.5 mm^2.

The figure, distance from the source, deflection, and incidence angle of the optical components are listed in Table II. All optics are assumed to have a Au optical coating. The third plane mirror, M2, is an integral part of the monochromator.

The meridional deformations of M0 and M1 will affect the horizontal spot size whereas those along their widths (multiplied by the forgiveness factor, the sine of the angle of grazing incidence on the mirror) will affect the monochromator resolution. For M2 and the grating, which deflect the beam along the dispersion direction (vertical plane), the effect of the meridional deformations affect the resolution and the sagittal deformations the horizontal spot size.

The highest power density absorbed by M0 is when the insertion device is tuned to emit the lowest photon energy, 250 eV. The maximum power density in this case is 0.55 W/mm^2 as seen in the image plot displayed in Fig. 1. The total absorbed power is 920 W.

TABLE I: Source parameters. $\sigma_{x(y)}$ is the electron beam size along the horizontal (vertical) direction and $\sigma_{x'(y')}$ is the electron beam divergence

Electron Energy (GeV)	7.0
Electron Current (A)	0.20
σ_x (μm)	275
σ_y(μm)	9.0
$\sigma_{x'}$ (μrad)	11.3
$\sigma_{y'}$(μrad)	3.0
ID period (mm)	125
Number periods	38

TABLE II: Figure, distance from the source, angle of incidence, and deflection of the optical components

Figure	Distance (m)	Grazing Angle (deg)	Deflection
M0: Plane	30.5	0.4	Horizontal
M1: Plane	31.3	1.5	Horizontal
Monochromator: M2	39.3-39.6	0.8-5.75	Vertical
Monochromator: Grating	39.7	1.4-6.3	Vertical

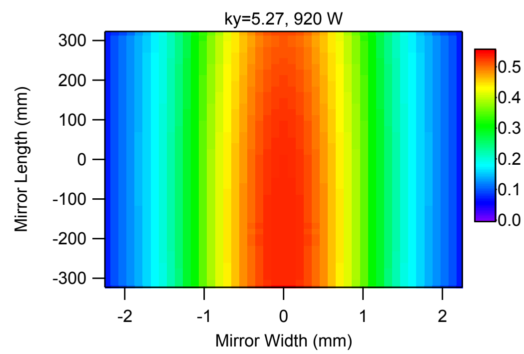

FIG. 1: Power density absorbed by M0 when the ID is tuned to 250 eV.

The highest power density absorbed by M1 is actually when the ID is tuned near 770 eV to emit either horizontal or vertical linear polarization. The image plot for the horizontal case is seen in Fig. 2 . With either polarization the absorbed power density is almost 0.45 W/mm^2 and the total absorbed power is near 280 W.

The results for M2 and the grating depend not only on the insertion device and the previous mirrors but also on the grating being used. For the same photon energy, a higher line density grating implies a smaller angle of normal incidence on M2 and therefore a higher power density. Fig. 3 shows the case where the insertion device is tuned to emit horizontally polarized radiation at 384 eV. The absorbed power density is slightly higher than 0.06 W/mm^2 and the total absorbed power is near 32 W.

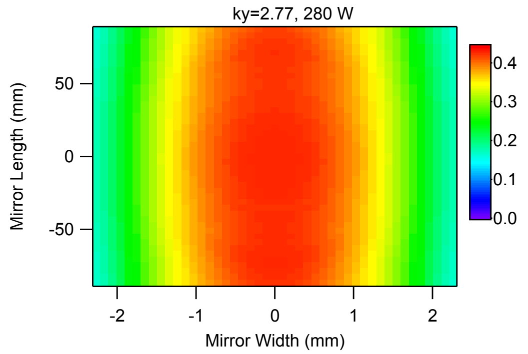

FIG. 2: Power density absorbed by M1 when the ID is tuned to emit horizontally polarized photons at 770 eV.

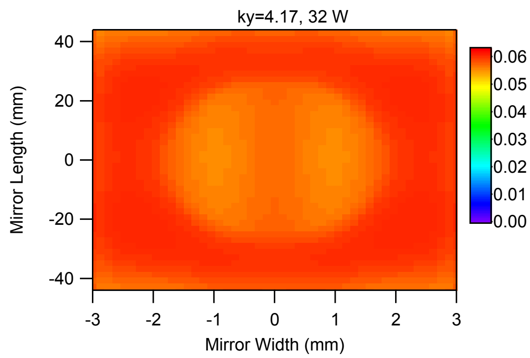

FIG. 3: Power density absorbed by M2 when the ID is tuned to emit horizontally polarized photons at 384 eV.

The grating absorbs the least power. Fig. 4 shows the case with the highest power density, approximately 12 mW/mm^2 and a total power of 10 W that occurs when the insertion device is tuned to emit horizontally polarized radiation at 770 eV and the grating has 400 l/mm.

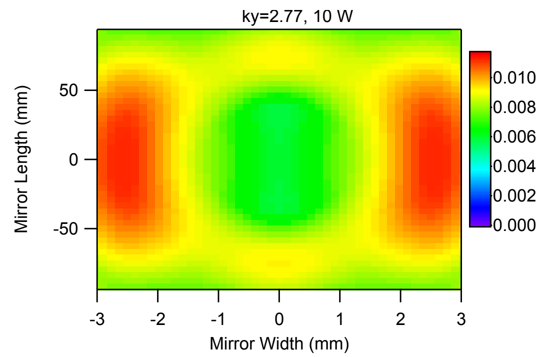

FIG. 4: Power density absorbed by the 400 l/mm grating when the ID is tuned to emit horizontally polarized photons at 770 eV.

[1] R. Reininger, *SRCalc* (2001-2009).

FEA Study

for M0 for the IEX Beamline on Sector 29 at the Advanced Photon Source

Written by: Ioannis Katramados

Reviewed by: Alexander Babkevich Date: 14 May 2010
Authorized by: Scott Mowat Date: 14 May 2010

May 2010
Version: 01

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Contents

1. Summary

FMB Oxford has conducted a preliminary FEA study for the M0 mirror optic for the IEX beamline on Sector 29 at the Advanced Light Source, Argonne National Laboratory, USA.

Effects of heat load due to x-ray beam and side water cooling of the substrate on the distortion of the optical surface were analysed. The aim of the study was to optimise the size and position of the undercut in order to minimise the thermal expansion and reduce slope errors.

The absorbed power distribution on the surface of the mirror was calculated analytically using Spectra 8 and XOP 2.3 packages.

The effects of increase in coolant temperature along the length of the cooling pipes were not included in the model. The input data of ambient temperature and heat transfer coefficients for the FEA models were calculated using general fluid- and thermodynamics.

The effect of the heatload on the mirror was analysed for the maximum operating condition described in the Statement of Work in the Call for Tender.

The M0 was analyzed in this case, however the heatload of M1 is such that it is likely to demonstrate the same behaviour as M0.

2. Introduction

This report summarises the boundary conditions and results of FEA study carried out for M0 mirror for the IEX Beamline at Sector 29 of the APS.

A model that includes a Silicon substrate of 600 mm (L) x 80 mm (W) x 50 mm (D) with side water cooling via side mounted copper blocks and an Indium film interface was used in the simulation. 3D CAD models were initially created using Solid Edge 20.0. The study was conducted using ANSYS v.11 finite element analysis (FEA) program.

An undercut at a distance of 10mm from the optical surface and a width of 5mm was chosen as the best starting point based on previous FE analysis. The depth of the cut was examined and 9mm was accepted as the best value to reduce slope errors.

Calculations of the flow rate and heat transfer coefficient are not provided here but are available upon request.

3. Specifications

3.1. Beam power

The power load used in this analysis was calculated using Specta 8.0 and XOP 2.3 packages. The most up-to-date parameters of the undulator source used in the calculations were as provided by the customer [1].

Source parameters:	E= 7 GeV
	I= 200 mA
	Undulator period: 12.5 mm
	Undulator length: 4.8 m
	Number of periods: 38
	Deflection parameter: K=5.27
Other constraints [1]:	Distance from source to M0: 30.5 m
	Horizontal beam opening angle at M0: 119 μrad (520mm long footprint at 0.4°)
	Vertical beam opening angle at M0: 147 μrad (4.5mm)
	Mirror coating: Au
	Mirror substrate: Si
	Mirror incidence angle: 0.4°
	Substrate size: 600 mm (L) x 50 mm (D) x 80 mm (W)
	Mirror orientation: horizontally deflecting

The resulting absorbed power of this case is 741W rather than the 920W defined in the CFT documents due to the reduction in horizontal acceptance from 4.5mm to 3.64mm.

The power distribution absorbed by the mirror is shown in Figure 1.

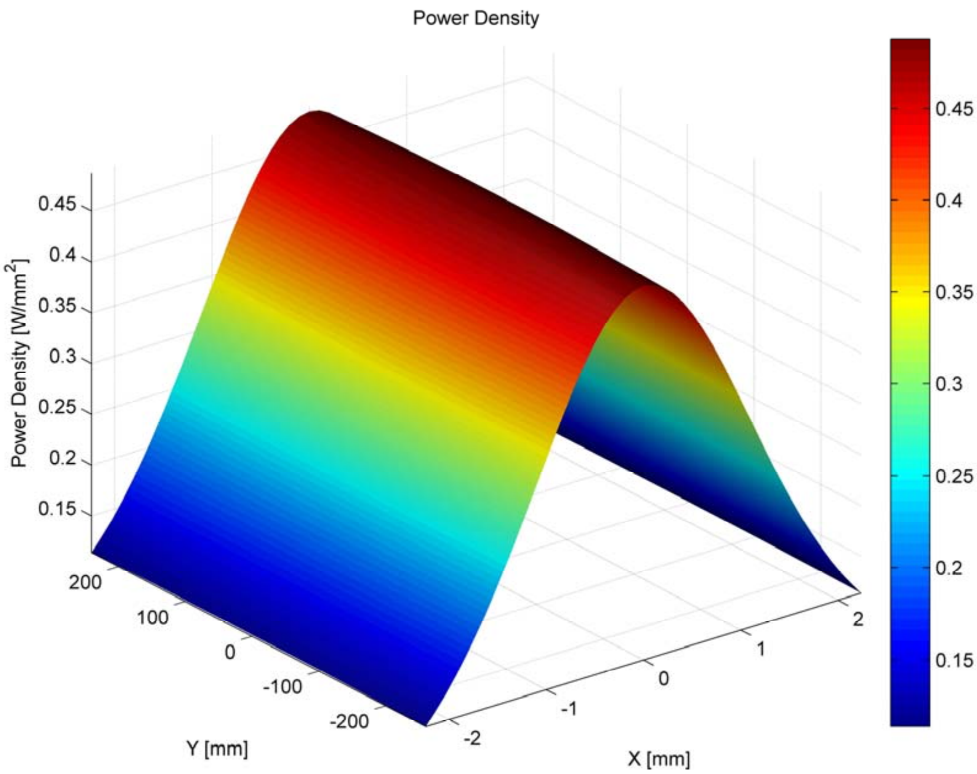


Figure 1. Distribution of absorbed power density. The Y direction is along the beam.

3.2. Mechanical Design

The design chosen is a side-cooled mirror substrate. Thermal interface between the substrate and the copper cooling blocks is assured by an Indium foil. The substrate will be manufactured from Si. The size of the substrate is 600 mm (L) x 50 mm (D) x 80 mm (W).

The cooling blocks will be pushed to the mirror substrate by a force of ~50 N per cooling clamp. There are ten cooling clamps at each side of the substrate.

4. Parameters of the model

4.1. Cooling & Clamping

Calculations for the water cooling system were performed but are not presented herein. The boundary thermal condition (Ambient Temperature) applied on the cooling pipes in FEA were an ambient temperature of 20˚ C plus calculated bulk temperature rise. The effect of temperature rise along the cooling channel was ignored.

A heat transfer coefficient was calculated between water and cooling channel and applied as a convection boundary along the whole length of the cooling lines.

The mirror was analysed with quarter symmetry and was modelled accordingly. The block is supported from its side with a frictionless support. The clamping effect of the cooling blocks was not modelled since from past experience it can be shown to be insignificant.

4.2. Properties of Materials and Interfaces

The substrate will be made of Si and the cooling blocks will be made of OFHC copper. The cooling pipes will be made of copper and brazed to the copper cooling blocks. The pipes themselves are modelled.

Mechanical and thermal properties of the materials are given in Table 1.

Table 1. Properties of Materials

Material Property	OFHC Cu	SiC
Young's Modulus	1.17×10^{11} Pa	1.558×10^{11} Pa
Poisson's ratio	0.35	0.2152
Density	8900 kg/m^3	2330 kg/m^3
Coefficient of thermal expansion	1.9×10^{-5} $^oC^{-1}$	2.616×10^{-6} $^oC^{-1}$
Thermal conductivity	396 W/(m · ^oC)	151.25 W/(m · ^oC)

Interface transfer coefficients were 4,000W/m2K between the Copper cooling block and the silicon substrate (via the Indium foil interface) and 9,000W/m2K between the copper cooling block and the copper cooling lines.

5. Results and Discussion

5.1. Temperature & stress distribution

The results for the temperature distribution in Si are given below in Figure 2 for an undercut of 9 mm.

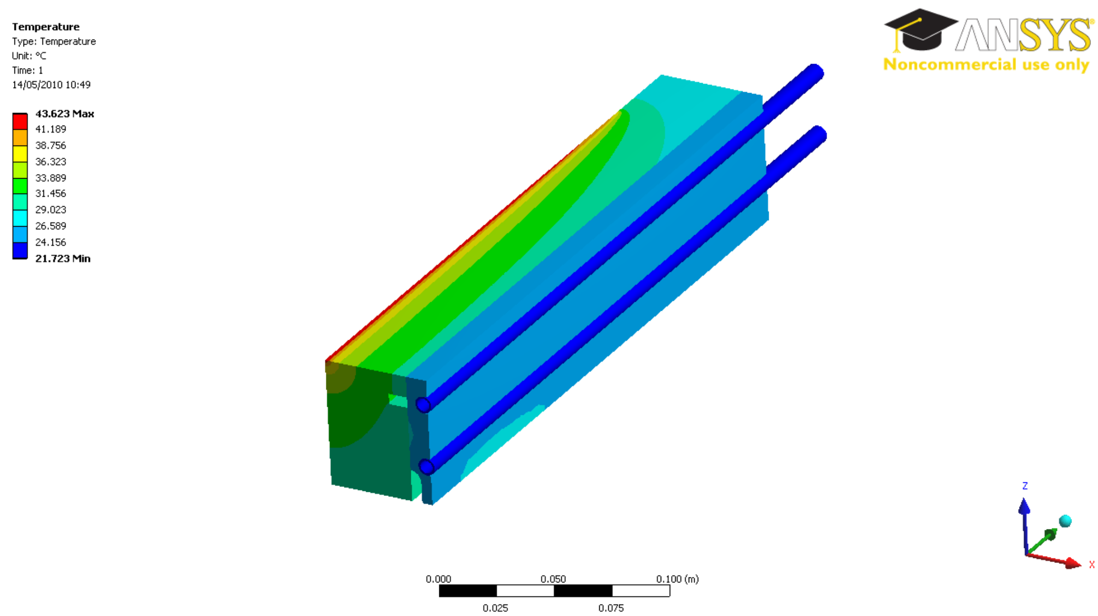


Figure 2. Temperature distribution on the substrate of the mirror

We have also calculated the equivalent (Von Mises) stress and the results in Figure 3 demonstrate the stress at an undercut depth of 9 mm.

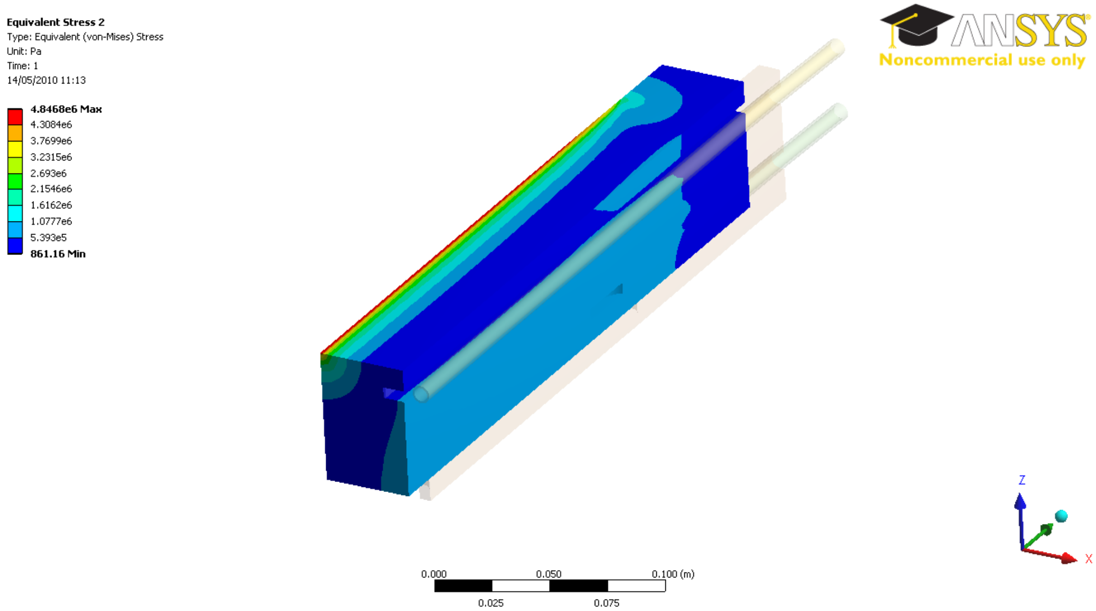
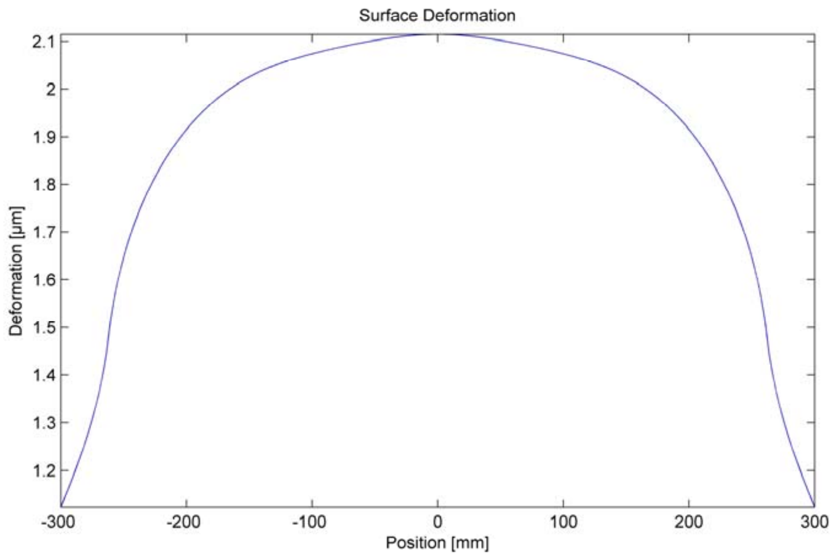


Figure 3. Calculated distribution of equivalent stress in the optics

Both the temperature and stress plots show good correlation with the preliminary FEA included in the Call for Tender Documents

5.2. Tangential Slope Error

The tangential slope error is the deviation from flat along the crystal length parallel to the beam under the operating thermal loads. Figure 4 shows the vertical displacements and slope errors at the centre of the beam footprint.



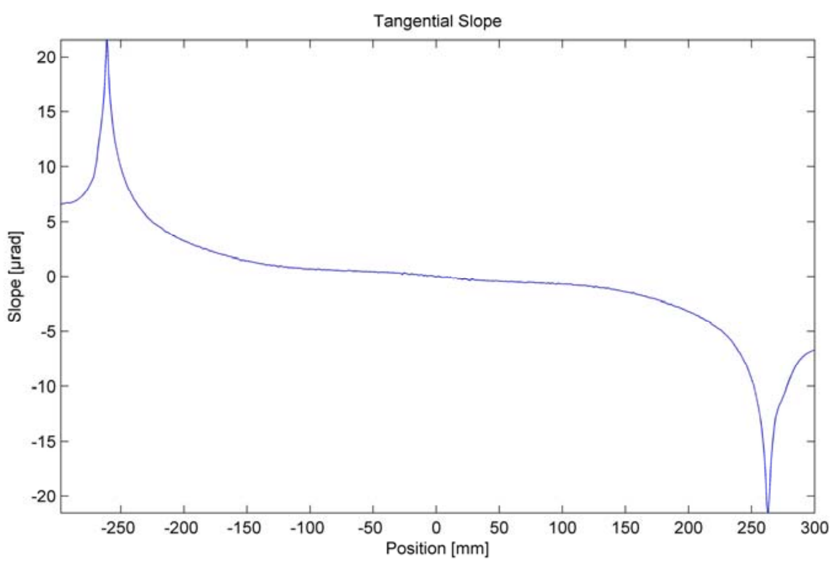
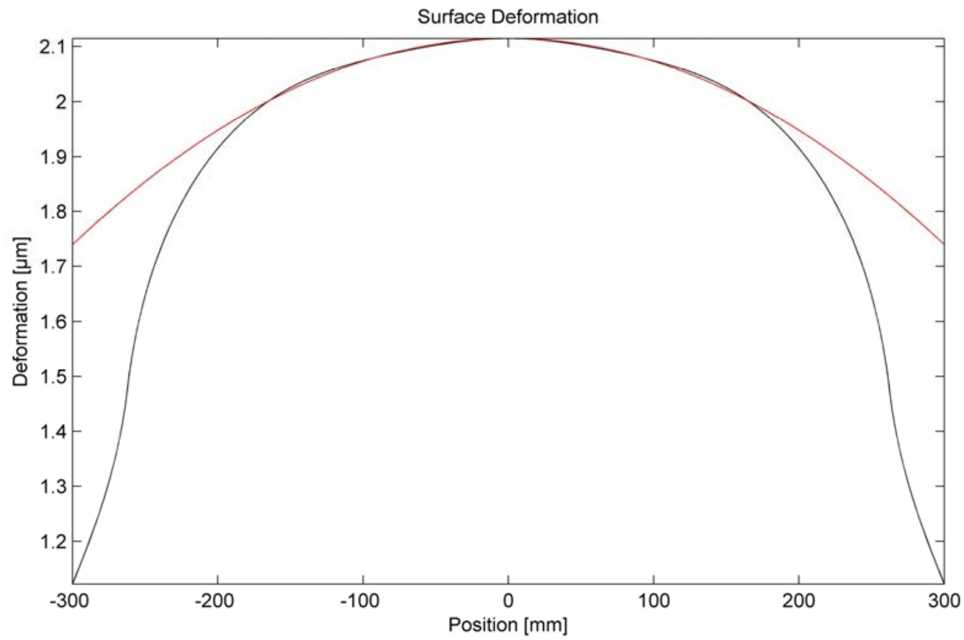


Figure 4. Variation of surface displacement and slope along the length of the mirror and associated slope error



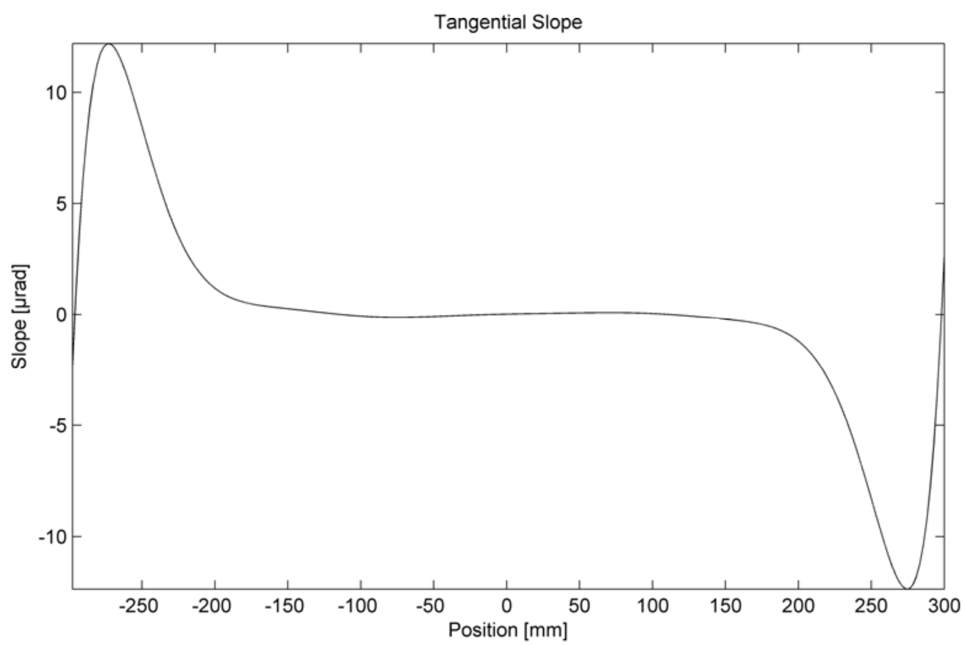
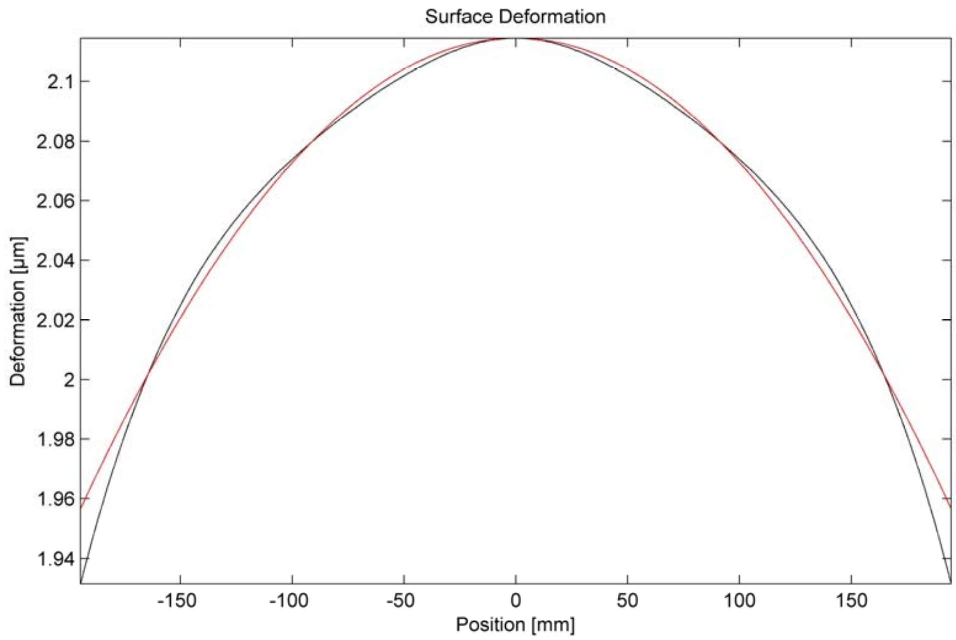


Figure 5. Variation of surface displacement and slope along the length of the mirror and 2.66 µad RMS corrected slope error after subtraction of R=120km



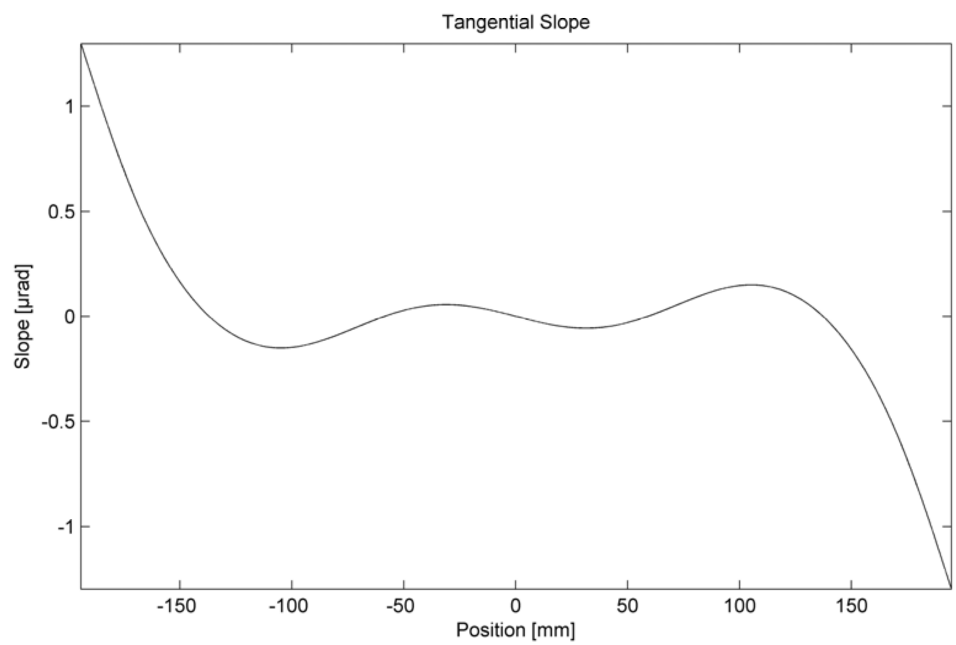


Figure 6. Variation of surface displacement and slope along 75% of the illuminated length of the mirror and 0.37 µad RMS corrected slope error after subtraction of R=120km

6. Conclusions

The results shown herein show good agreement with those presented in the supporting documents of the Call For Tender.

For an undercut of 9mm, the best fit radius is 120km, much larger than the 10km radius required, so this is more than satisfactory.

The associated slope error over the total illuminated length is 2.66 μrad RMS and 0.37 μrad RMS for 75% of the illuminated length.

If these slope errors are cause for concern to improve the performance we could consider opening up the white beam slits to increase the acceptance and increasing the length of the M0 substrate to 770mm and the M1 substrate to 350mm and illuminating them over the full length. Downstream horizontally-defining slits could then trim off the beam reflected at either end of the optics to achieve better than 0.25 μrad RMS off each optic for the required beam acceptance.

This can be done at minimal incremental cost and may be worthwhile considering that the effect on the beam from M0 is then repeated again on M1 immediately downstream.

References

1. Statement of Work for IEX Mirror Systems M0 and M1 (Document No 43290804-00001-00).

EPS Componet List
8/9/12

Vacuum Sensors
VS1A
VS2A
VS3A,B
VS4B
VS5B
VS6B
VS7C
VS7C-1
VS8C
VS9C
VS10C
VS6D
VS7D
VS8D
VS9D
VS10D

Gate Valves	
V1A	4.5" all metal
V2A	6" all metal
V3B	4.5" all metal
V4B	4.5" all metal
V5B	4.5"
V6C	2.75"
V7C-1	2.75" manual with Al window
V7C	2.75"
V8C	4.5" all metal
V9C	2.75" all metal
V6D	2.75"
V7D	4.5"
V8D	4.5" all metal
V9D	2.75" all metal

Ion Pumps	
IP1A	200 L/S in-line
IP2A	M0/M1 Gamma Vacuum 500T
IP3A	200 L/S in-line
IP3B	200 L/S in-line
IP4B	Mono Gamma Vacuum 600LX
IP5B	200 L/S in-line
IP6B-1	200 L/S in-line
IP6B-2	200 L/S in-line
IP6C	200 L/S in-line
IP6D	200 L/S in-line
IP7C-1	200 L/S in-line
IP7C-2	200 L/S in-line
IP8C	200 L/S in-line
iD9C-1	TBD
IP9C-2	TBD
IP7D-1	200 L/S in-line
IP7D-2	200 L/S in-line
IP8D	200 L/S in-line
IP9D-1	TBD
IP9D-2	XIA Diff Pump

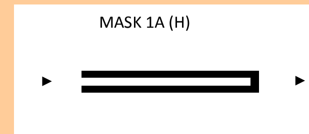
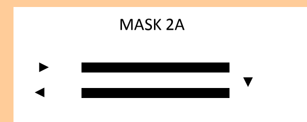
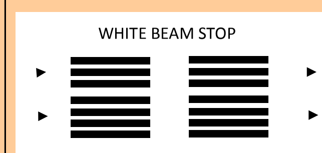
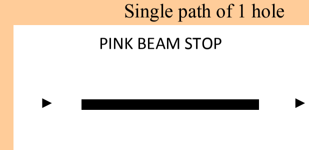
Temperature Sensors and Water Cooling
slits1A (water flow only)
D2A (Diagon/Wmesh)
M0/M1
M2/grating

* VS7C-1, V7C-1 part of Gas-Cell

Motion	
D1A	
(wire)	Linear feedthrough

29-ID IEX Beamline Radiation Safety System and White Beam Slit - Component Cooling Requirements

Notes:
1) Beam Conditions: Ring current 200 mA, minimum undulator gap 10.5, (K = 5.27 Max.) , undulator period length 2.5 cm, number of periods 38.
2) For thermal caculations see APS_...pdf
3) For component locations see APS_.....pdf

Component	Location (m)	Drawing Number	Number of coolant holes	Number of parallel paths	Number of series paths	Holes per series paths	Total flow (normal operation) (gpm)	Total flow (at trip) (gpm)	Flow per hole at trip (gpm)	Beam condition (Note 1)	Calculated convection coefficient ($W/m^2.C^o$)	Flow configuration and comments
MASK 1A (H) (Mask)	31.5	4105091012 -101200	1	1	1	1	4.0	2.4	2.4 (= 2.4 / 1 / 1)	Focused, Pink	19603 (no coil)	Inside in, outside out 
MASK 2A (V) (Mask)	32	4105091012 -101300	2	1	2	1	4.0	2.4	2.4 (= 2.4 / 1 / 1)	Focused, Pink	9449 (no coil)	Top 1 hole in series with bottom 1 hole 
WHITE BEAM STOP	32.5	4105091012 -101020	14	2	2	3	4.0	2.4	0.8 (= 2.4 /3 / 1)	White	3923 (no coil)	Top set of 3/4 holes in series with bottom set of 3/4 holes 
						4	4.0	2.4	0.6 (= 2.4 /4 / 1)	White	3117 (no coil)	
PINK BEAM STOP	42.4	4105091008 -100700	1	1	1	1	4.0	2.4	2.4	Focused, Pink	9449 (no coil)	Single path of 1 hole 

Christa Benson
Jie Liu
5/14/12

29-ID IEX Beamline Radiation Safety System and White Beam Slit - Component Cooling Requirements

EPS SLITS 1A (H+V)	29	4105091501 -100000	8	1	4	2	4.0	2.4	1.2 (= 2.4 / 2/ 1)	White	17141 (with coil)	Single path of 2 holes in series